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1799

*Notified in  
Army Orders for  
December  
1937*



# Small Arms Training

Volume I Pamphlet No. 10

## Infantry Range- finder

1937

(MODIFIED FOR AUSTRALIA)

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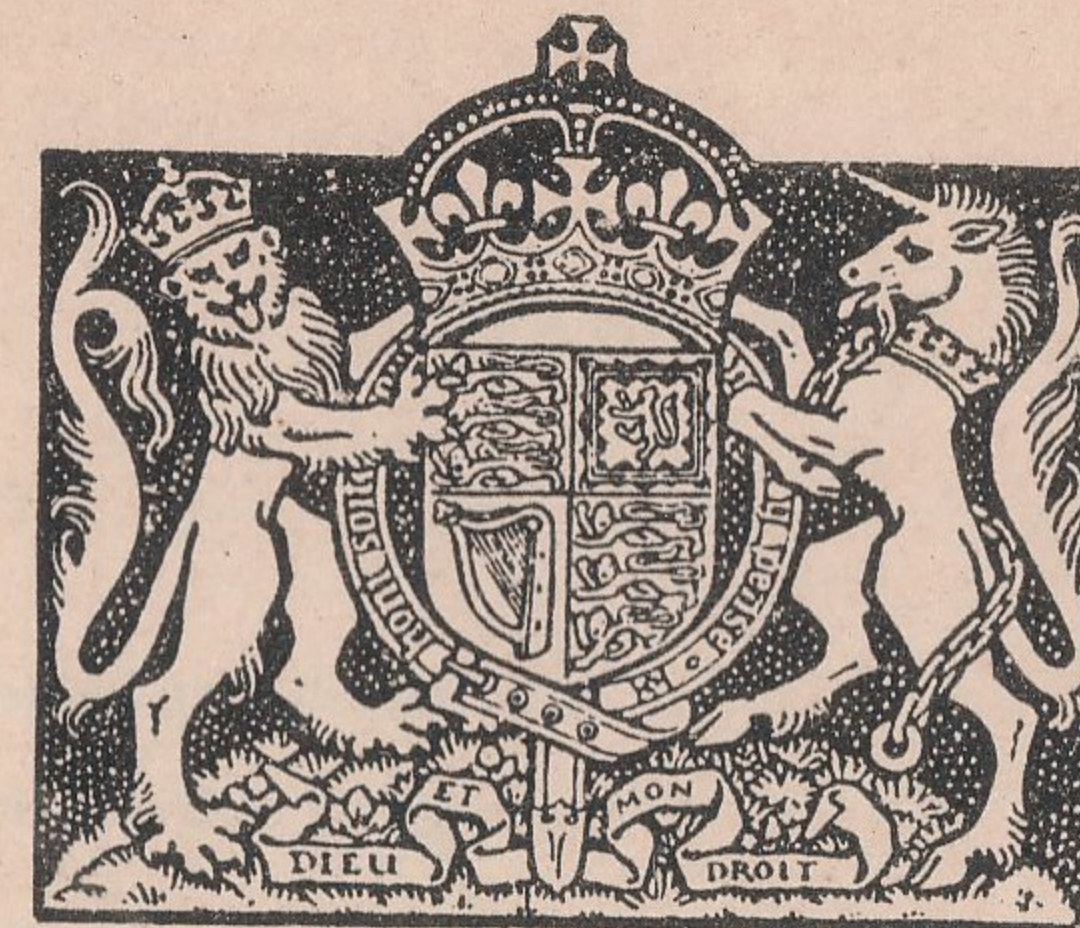
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# **Small Arms Training**

**Volume I Pamphlet No. 10**

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By Command of the Army Council,

*H. J. C. 2*

THE WAR OFFICE.  
31st December, 1937.

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## DEFINITIONS

**Mean observed range (M.O.R.)** is the mean or average of a series of readings on the same object. It is found by dividing the total of the series by the number of readings.

**Mean deviation (M.D.)** is the difference between the *mean observed range* and the *true range* to the object. It is recorded as plus or minus, according to whether the M.O.R. is above or below the true range.

**r** is the range in thousands of yards.

**Accuracy figure (A.F.)** is a measure of the accuracy with which a range has been taken. It is found by dividing the mean deviation by  $r^2$  of the true range.

**Consistency figure (C.F.)** is a measure of the consistency or "size of the group" of a series of readings. It is found in the following way:—

Find the difference between the M.O.R. and each reading ; these figures are the *residuals*.

Divide the total of the residuals by the number of readings ; this figure is the *mean residual*.

Divide the mean residual by  $r^2$  of the M.O.R. ; this gives the *consistency figure*.

## SECTION 1.—IMPORTANCE OF RANGE-TAKING

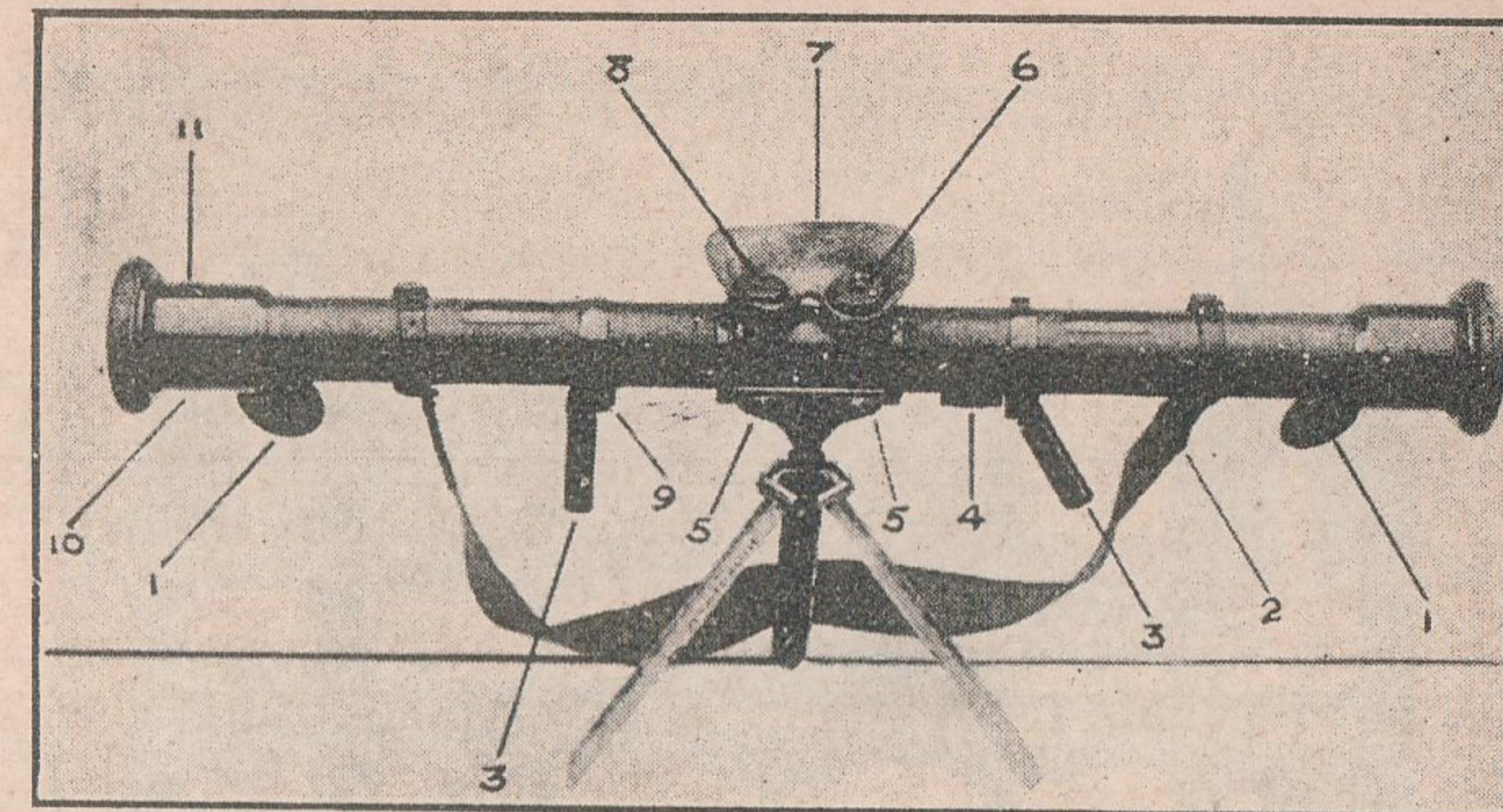
1. Machine guns cannot obtain fire effect at long ranges, neither can the safety of our own troops be assured when fire is over their heads unless the range is accurately known.

2. Ranges for machine gun purposes may be obtained either by range-finder or from a map of not less than 1/25,000; but, as on a map it is often difficult, or even impossible, to identify the exact positions of guns, target and own troops, the range-finder is likely to be the normal method used, except when all calculations are made from a map, as in map shooting.

3. The allowance made in machine gun fire control and safety rules to cover errors in range is 5 per cent. The maximum error which might be made by trained range-takers under service conditions is  $2\frac{1}{2}$  per cent. per 1000 yards; thus the range obtained should be within 5 per cent. up to 2000 yards.

PLATE I

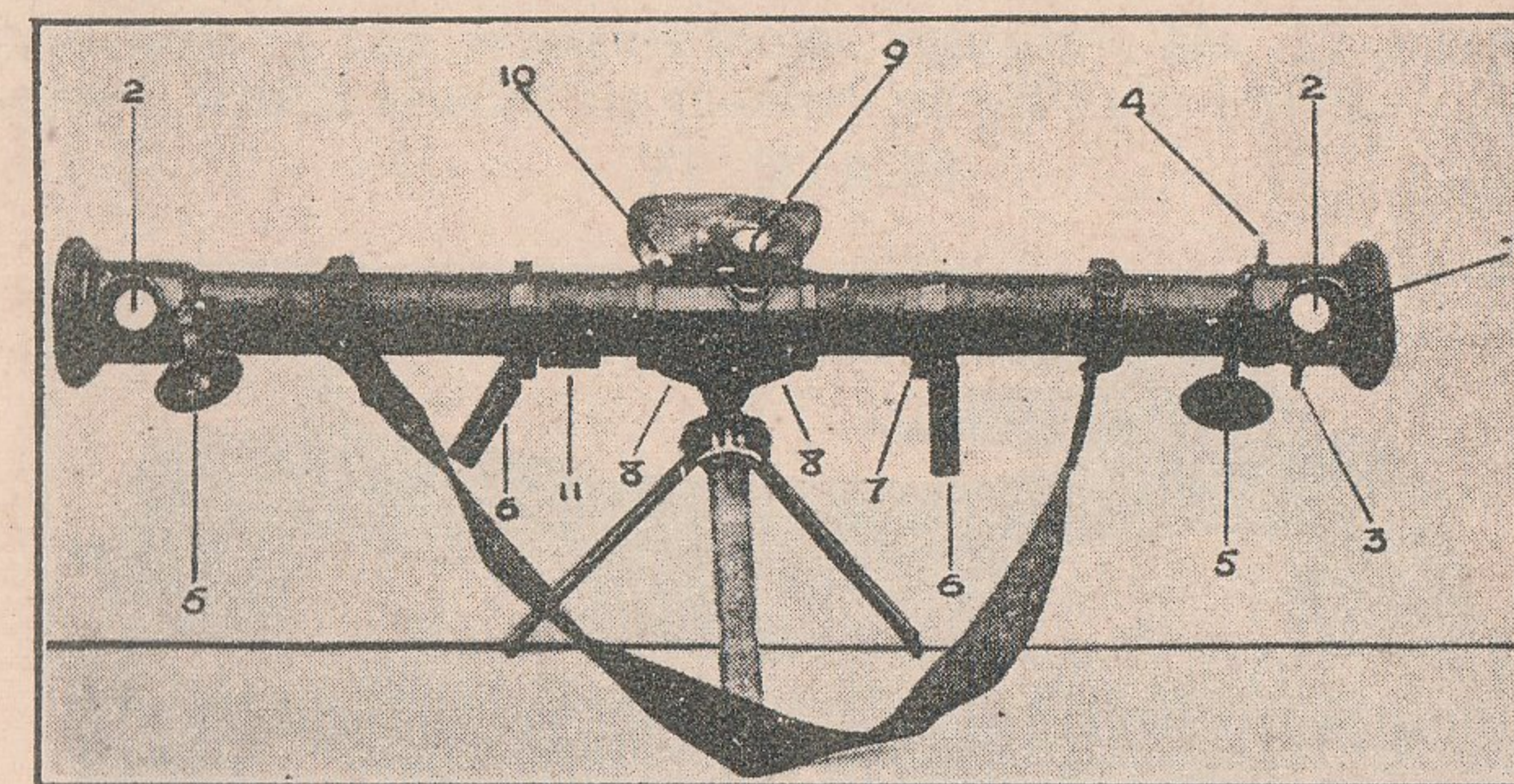
[Facing p. 6.]



Infantry range-finder. View from rear.

- |                            |                                 |
|----------------------------|---------------------------------|
| 1. Window caps.            | 6. Right eyepiece.              |
| 2. Sling.                  | 7. Rubber facepiece.            |
| 3. Right and left handles. | 8. Left eyepiece.               |
| 4. Working head.           | 9. Astigmatizer lever.          |
| 5. Carrier.                | 10. Halving adjusting head.     |
|                            | 11. Coincidence adjusting head. |

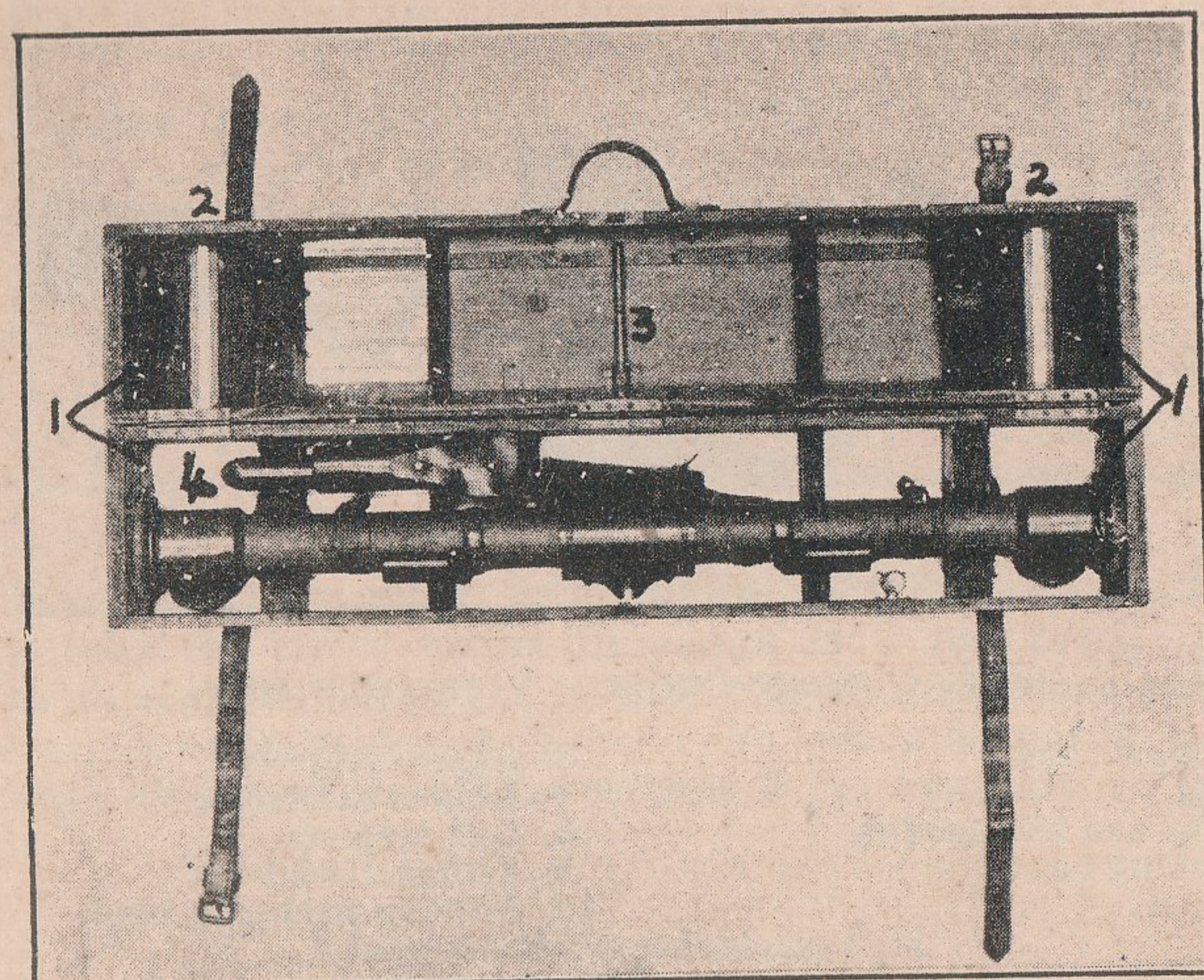
PLATE II



Infantry range-finder. View from front.

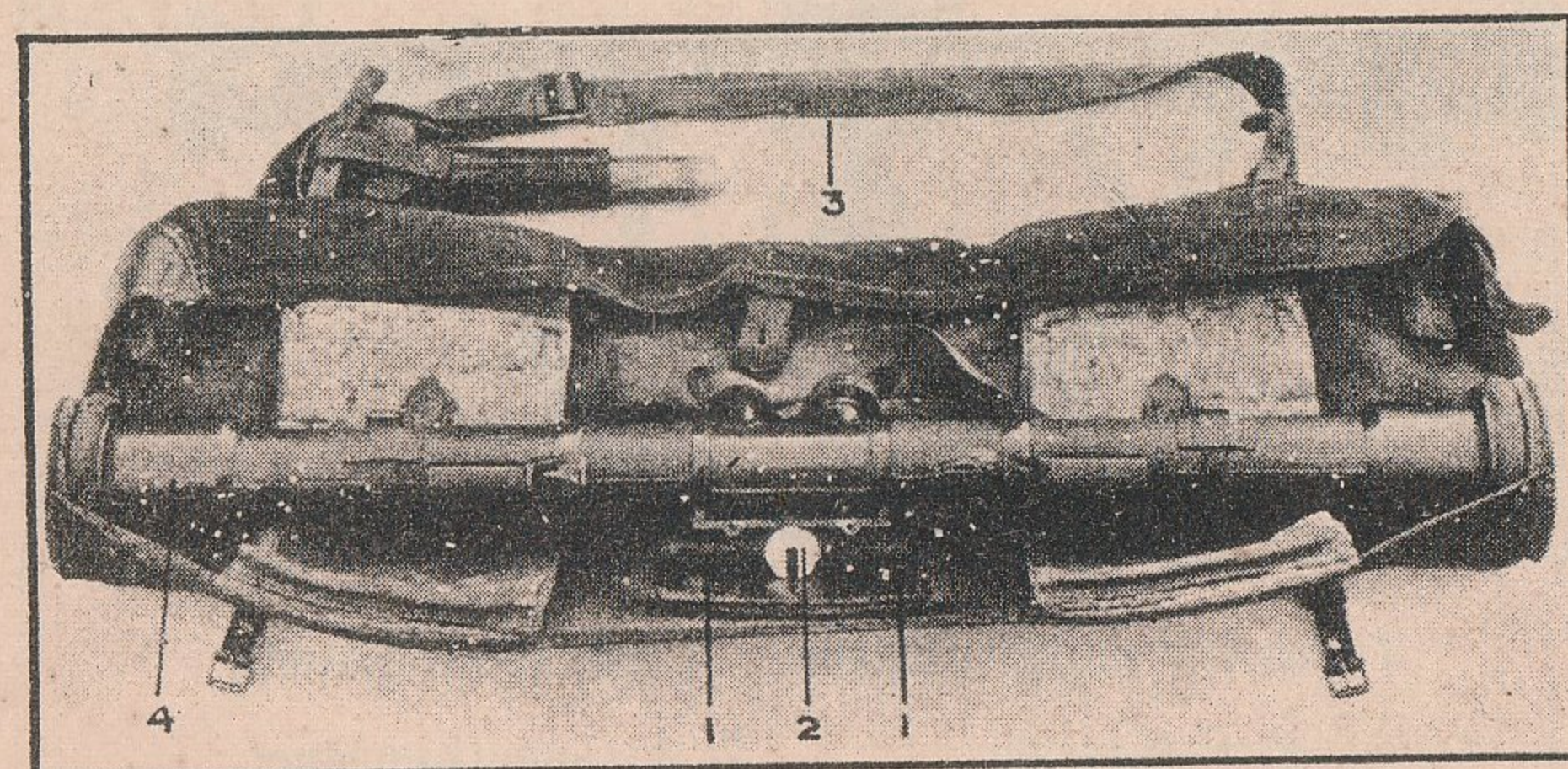
- |                                    |   |
|------------------------------------|---|
| 1. Coincidence adjusting scale.    | 7. Astigmatizer lever.                        |
| 2. Left and right windows.         | 8. Carrier.                                   |
| 3. Halving adjusting head flap.    | 9. Front range scale window cover and window. |
| 4. Coincidence adjusting head flap | 10. Focusing lever.                           |
| 5. Window caps.                    | 11. Working head.                             |
| 6. Left and right handles.         |   |

NOTE.—The instrument illustrated is the Mk. V.



Infantry range-finder in wooden case.

- |                     |                           |
|---------------------|---------------------------|
| 1. Felt pads.       | 3. Supporting rod.        |
| 2. Laths adjusting. | 4. Stand in leather frog. |



Infantry range-finder placed in canvas cover ready for packing.

- |                          |                                 |
|--------------------------|---------------------------------|
| 1. Leather pad on cover. | 3. Web sling.                   |
| 2. Carrier.              | 4. Halving adjusting head flap. |

## SECTION 2.—DESCRIPTION OF THE RANGE-FINDER

1. The names of parts of the range-finder, etc., are given in Plates I to IV. The following information will also be useful :—

Base length of instrument	80 cm. (approx. $\frac{7}{8}$ yard).
Weight of range-finder.	10 lb. 6 oz.
„ „ case.	16 lb.
„ „ cover.	4 lb.
„ „ stand and frog.	1 lb. 4 oz.
Magnification of right eyepiece, about 14 diameters.	
„ „ left „ „	3 „
Dimensions of field of view—	
Width ... ..	About 3 degrees.
Height of upper field ... ..	„ $1\frac{1}{2}$ „
„ lower „ ... ..	„ $\frac{3}{4}$ degree.

2. In order that the delicate mechanism required to measure very small angles may be able to withstand rough usage in the field, the mechanism is mounted in an inner frame, with no rigid connection between it and the outer tube of the range-finder. The range-finder is thus made sufficiently robust to be carried in its case on a horse or in any form of mechanical transport without damage or loss of adjustment.

3. Further details of the instrument will be found in the Handbook of the Range-Finder, Infantry, No. 12 (Barr and Stroud), which should be studied by all instructors.

### SECTION 3.—THEORY

1. The range-finder measures an angle. This is the angle subtended by the base length of the instrument at the object. As the base length is small compared with the range, the angle is very small, the largest angle measured being about 12 minutes, which is at the shortest range marked on the range scale—250 yards.

The instrument is so constructed that rays of light from an object enter the left window at right angles to the base of the instrument, and those entering the right window leave the object at an angle. When coincidence is made, the measurement of this angle gives the range, which will be indicated in yards on the range scale. Plate V (page 14) shows the range scale reading 1000 yards.

2. In every coincidence there is a small error, and to obtain a reliable range it is necessary to take a series of readings and find the mean, when the errors in the individual coincidences will to a large extent average out. The mean of ten readings is used normally and, even for quick work, the mean of less than four readings must never be accepted as a range.

3. Any error in determining a coincidence will be an error in the angular measurement. The same angular error, as found in yards, increases as the square of the range. Thus the standard set, by which a range-taker's results are to be judged, must be in terms of the square of the range. The basis of calculation is  $r^2$ , where  $r$  is the range in thousands of yards.

4. Owing to variation of light and temperature errors in adjustment of the range-finder are unavoidable. To give the best results it must be adjusted (Sec. 8) under the same conditions as will exist when taking ranges. The trained range-taker should be able to judge the conditions and put a suitable setting on his instrument.

5. The range-finder gives different readings when coincidence is made in different parts of the field of view, and the centre of the field of view must therefore always be used.

### SECTION 4.—SELECTION OF RANGE-TAKERS

1. Instructors will be trained on range-finding courses at the Small Arms School, Randwick, or at local small arms courses held by formations. They should be trained to a fair standard of efficiency in their units before attending these courses; it is an advantage if they have at some time been trained range-takers.

2. A range-taker who has once been trained to a high standard, but has not kept in practice, can regain his former standard quickly, but while out of practice he cannot expect to obtain accurate ranges.

3. Men selected for training as range-takers should have the following qualifications:—

- i. Second class certificate of education.
- ii. Good and normal eyesight.

Although possessing these qualifications, some men will never become good range-takers; therefore the number of men in a class at the start should exceed the number of fully trained men required.

4. A man who wears glasses to correct short or long sight need not wear them when taking ranges, as the focusing lever can normally be adjusted to make the same correction as is made by his glasses; such men are therefore not unsuitable for training as range-takers. A man who wears glasses to correct astigmatism, however, should not be selected for training, as he must wear his glasses always to avoid eye-strain, and the glasses prevent him from placing his eye in the correct position in front of the eyepiece.

## SECTION 5.—TRAINING—GENERAL REMARKS

### 1. System of training.—

- i. Each stage in training should be introduced by one or more simple lectures by an officer, after which instruction should be continued by a N.C.O. During practical instruction each two men should work with one instrument, each in turn assisting and checking the other.
- ii. As a general principle the range-taker should be taught only what he should see in the field of view and what he has to do to produce the correct picture. The instructor should know in addition something of the working and theory of the instrument, details of which will be found in the Handbook of the Range-Finder.
- iii. A suggested syllabus for the training of new range-takers is given in Appendix I. This four weeks' syllabus should be sufficient to make the normal man a trained range-taker, although every opportunity for practice should be taken by the trained range-taker.
- iv. It will be found that, if suitable men are chosen for training, they will be able to take accurate ranges, provided that it is uninterrupted, after about three weeks' training. A fourth week will be required to teach them a range-taker's duties in the field.
- v. Throughout training, the last half hour of each day's work should be devoted to the completion of records, a discussion of the day's results and a revision of previous work.
- vi. Every man should be given a notebook when he begins training, and every reading taken by him will be noted in the book, with the exception of trial readings at the beginning of a series. A specimen page from a notebook is as follows :—

Date...	...	...	...	17th May.
Weather conditions	...	...	...	Bright and warm.
Setting used	...	...	...	R 2.4
Object	...	...	...	Bush (2).

1725	
1715	
1700	
1745	
1695	True range 1762
1715	M.O.R. 1722
1725	
1765	M.D. 40
1755	
1705	$r^2 = 1.8 \times 1.8 = 3$
1700	
1715	A.F. = $\frac{40}{r^2} = \frac{40}{3} = 13$
<hr/>	
10)17220	
<hr/>	
1722	

### 2. Stages in training.—

- i. Introduction to the instrument and how to take ranges.
- ii. Practice in taking ranges to easy objects.
- iii. Taking ranges to more difficult objects.
- iv. Adjustment of the instrument to suit weather conditions.
- v. Use of cover and field duties.

## SECTION 6.—GENERAL DESCRIPTION—PACKING AND UNPACKING—CARE AND CLEANING—SETTING UP AND FOCUSING

### *Instructor's Notes*

*Stores :—*

*The range-finding instrument in case.*

### Lesson 1.—General description—Packing and unpacking

1. **General description.**—The instructor will introduce the instrument, naming the parts, *see* Sec. 2 and Handbook of the Range-Finder, Infantry, No. 12 (Barr and Stroud), 1933, pages 13 to 17 only.

#### 2. Packing and unpacking.—

i. *To transfer the instrument from case to cover.*—Should the lid of the case be very tight, the catch should be pressed and the lid given a slight jar upwards and to the rear with the palm of the hand.

The position of the instrument in the case should be memorized, and the difference between the lid and the bottom of the case noted.

The instrument is taken out of the case and laid in the cover, with the carrier inside the leather pad to prevent it from tearing holes in the cover.

The cover is closed, and all straps and buttons fastened, the stand being attached to the strap at the double end of the sling.

ii. *Packing the instrument in the case.*—The carrier of the instrument must be as near the range scale window as possible, the handles towards the front of the case, and the right of the instrument on the right of the case. The case should be closed gently without force; should it fail to close, the following may be the cause :—

- (a) Instrument laid in the case the wrong way round.
- (b) Carrier misplaced or sling underneath.
- (c) Felt pads at end of the case rucked.
- (d) End windows not closed (Mk. III).

*Note.*—The case should never be carried with the straps unfastened.

### Lesson 2.—Care and cleaning

1. Although the range-finder is designed to withstand service conditions, it is necessary to guard against excessive jolting such as might occur if the instrument were dropped. Such treatment may cause loss of adjustment or even breakage. The range-finder should always be in its case when in transport, and in its cover when carried.

2. It is important that the range-finder be protected from damp. If used in the rain, it must be wiped dry before replacement in its case or cover, and must never be stored in a wet case or cover.

3. The windows and eyepieces must be kept clean, and should be covered except for actual range-taking. No oil or grease must be allowed to get on them, and they should never be touched by the hands. To clean the glass surfaces, use a clean piece of soft linen, silk or tissue; failing this, a clean piece of dry flannelette may be used. The glass must be rubbed firmly in one direction only, with a fresh piece of cloth for each stroke to avoid scratching the surface with grit already collected.

4. External metal surfaces should be cleaned with a dry cloth. Parts from which the paint or browning has worn may be wiped over with a slightly oiled rag before cleaning. A feather may be used for the crevices. Abrasives or metal polish must not be used.

5. The rubber facepiece should be removed periodically and washed in warm water. It must be thoroughly dried before replacement.

6. The instrument should not be exposed to gas if this can be avoided. When gas is present, it should be covered up, preferably in its case or cover, and afterwards the outside should be cleaned. If the outside of the instrument becomes contaminated, it should be washed carefully with petrol or paraffin, care being taken that no liquid penetrates the inside. Bleach paste must not be used. If it is thought that gas has penetrated to the inside of the instrument, it should be handed in to the ordnance workshops.

### Lesson 3.—Setting up and focusing

1. The instrument will be removed from the case or cover, and the stand attached. It will then be mounted on its stand facing in the required direction, the windows and eyepieces will be uncovered, and the astigmatizer lever pressed down.

3\*—(287)

2. The coincidence adjusting scale (Fig. 7, page 19) on the left window will be placed at the required setting by turning the coincidence adjusting head. The setting will be described as "Left (or right) so many divisions (and decimal fractions of a division)." The description "Left" or "Right" will be made when the scale is looked at the right way up, a scale which is actually at the bottom of the window being looked at over the top of the instrument, so that it appears as if it were at the top of the window.

3. The instrument must be mounted in such a way that the view to the front is unobstructed and the range-taker can assume a comfortable and steady position behind his instrument.

The range-taker's position should normally be lying, although sometimes it may be possible to mount the instrument on a vehicle or bank, etc. In such cases the most suitable position will be adopted.

The instrument must be held by the handles, the body supported on the elbows, and the forehead rested lightly on the rubber facepiece.

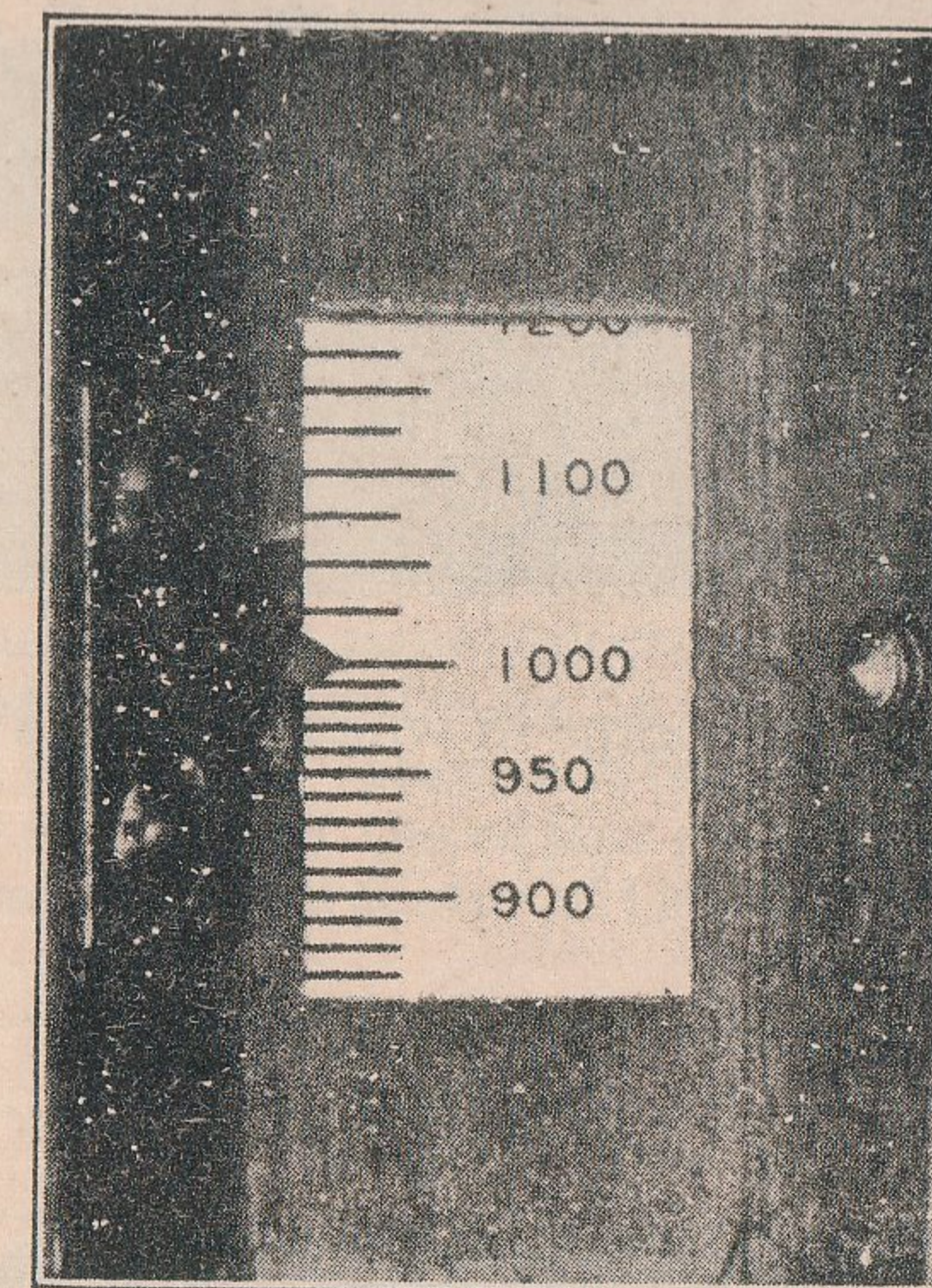
When an anti-gas respirator is worn, the rubber facepiece of the instrument may have to be removed temporarily.

4. The instrument will be focused in the following way :—

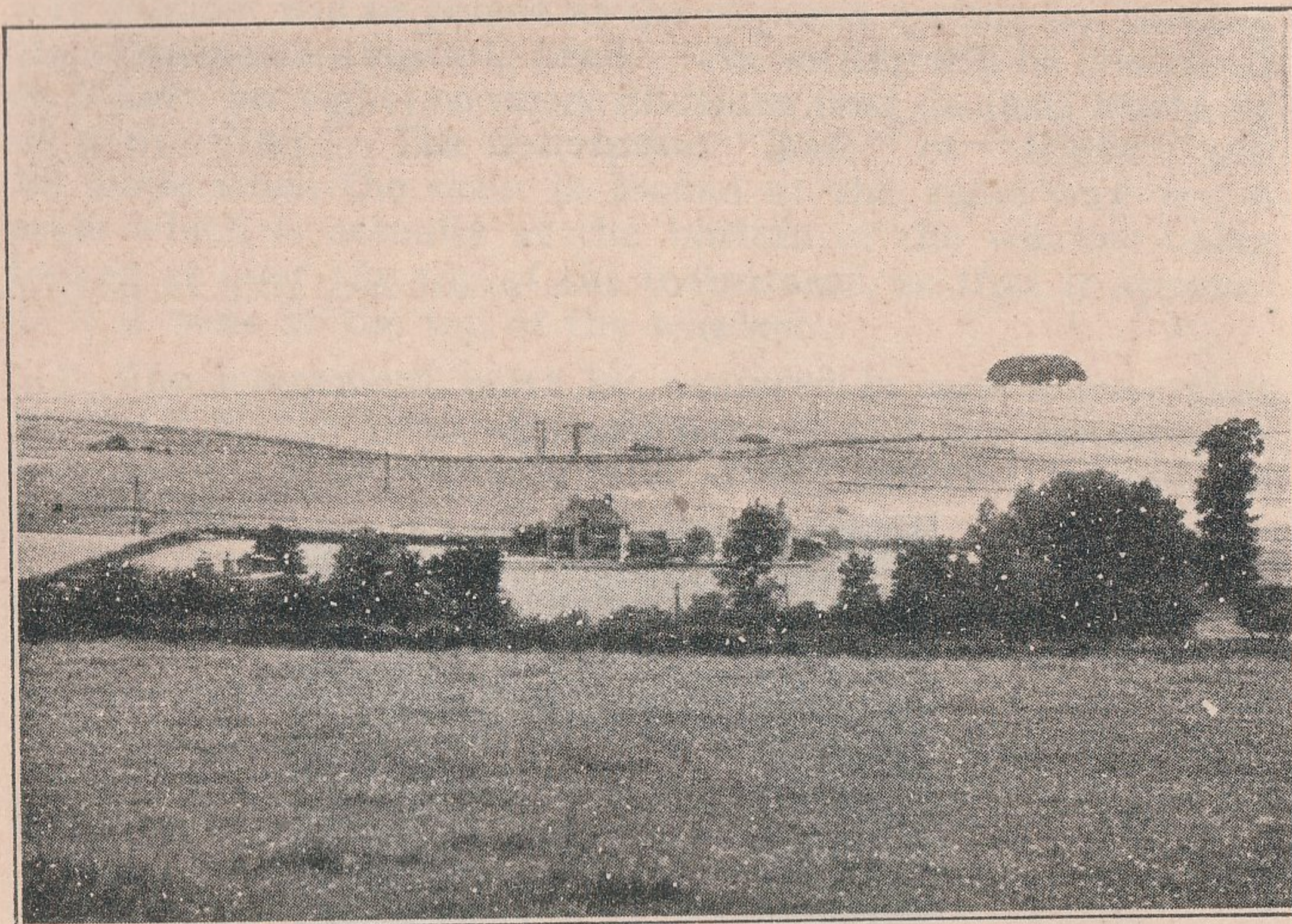
The eyes will be rested for a short time on a distant object, and then placed to the facepiece. The focusing lever will be moved until the dividing line appears to be as thin and clear as possible against the sky. If this is done correctly, all objects in the field of view will appear sharp and clear (except those at very short ranges), and, by accustoming the eye to a distant object before focusing, the focus will be such as to keep the eye at rest while taking ranges.

The instrument should never be directed at the sun. If this is done, both the instrument and the man's eyesight will suffer.

## PLATE V

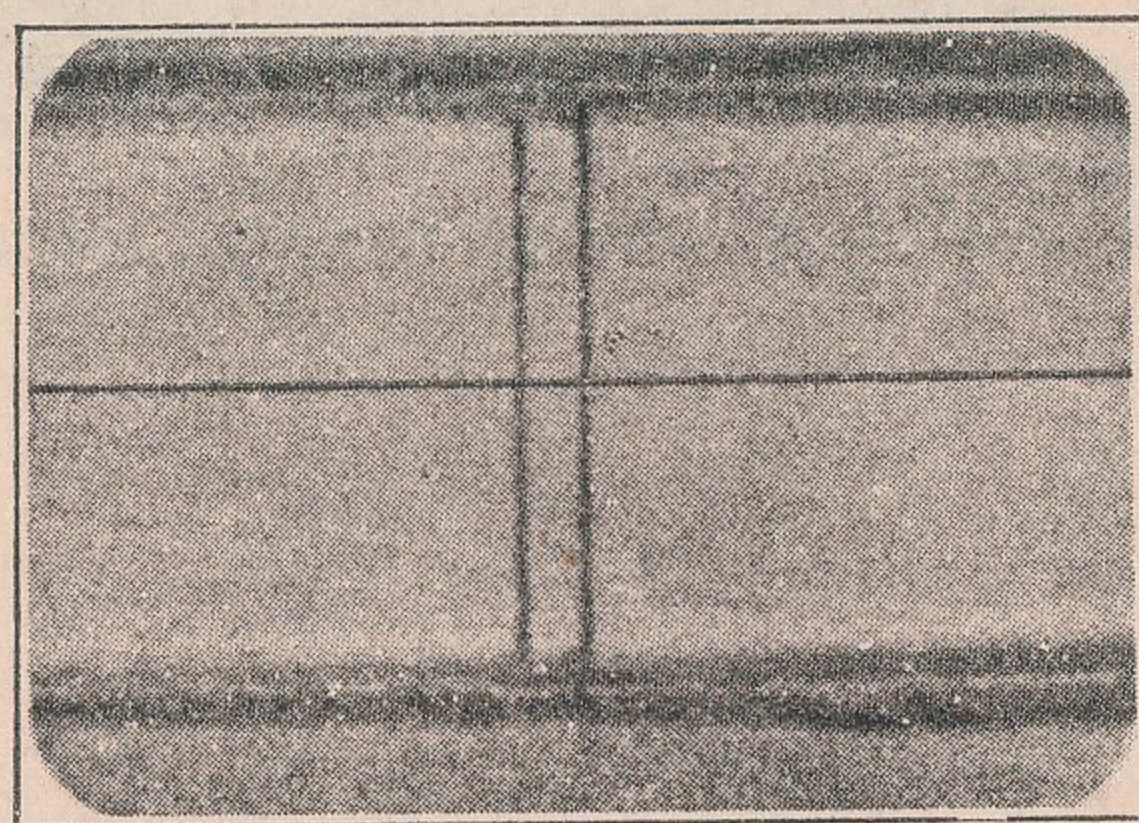


View of range scale as seen through left eyepiece.



View of landscape in which object (T) lies.

PLATE VII



Coincidence of object T in landscape, Plate VI, as seen in the field of view.

*Note.*—The house below the object can be used as an aid to picking up the object in the field of view.

## SECTION 7.—COINCIDENCE

### Lesson 4.—Making coincidence and reading scale

#### *Instructor's Notes*

*Lay stress on the importance of making coincidence in the centre of the field of view.*

*Check any tendency to slow and deliberate making of coincidences.*

*Insist that any coincidence that is "brought back" is cancelled; it breaks the sequence of coincidences from alternate sides.*

*Work out each man's adjustment for his day's work.*

*Ensure that all instruments are correct for halving.*

1. The range-finder will be turned until it is square with the object, and then turned in its carrier until the object can be seen in the field of view. The object will always be kept in the centre of the field of view.

2. **To make coincidence**, the working head will be turned until the two images of the same object are cutting the dividing line at the same point on the images, in the centre of the field of view (Plates VI and VII). There will be a considerable error in range if the actual part of the object on which coincidence is made is not exactly in the centre of the field of view (Figs. 1, 2 and 3).

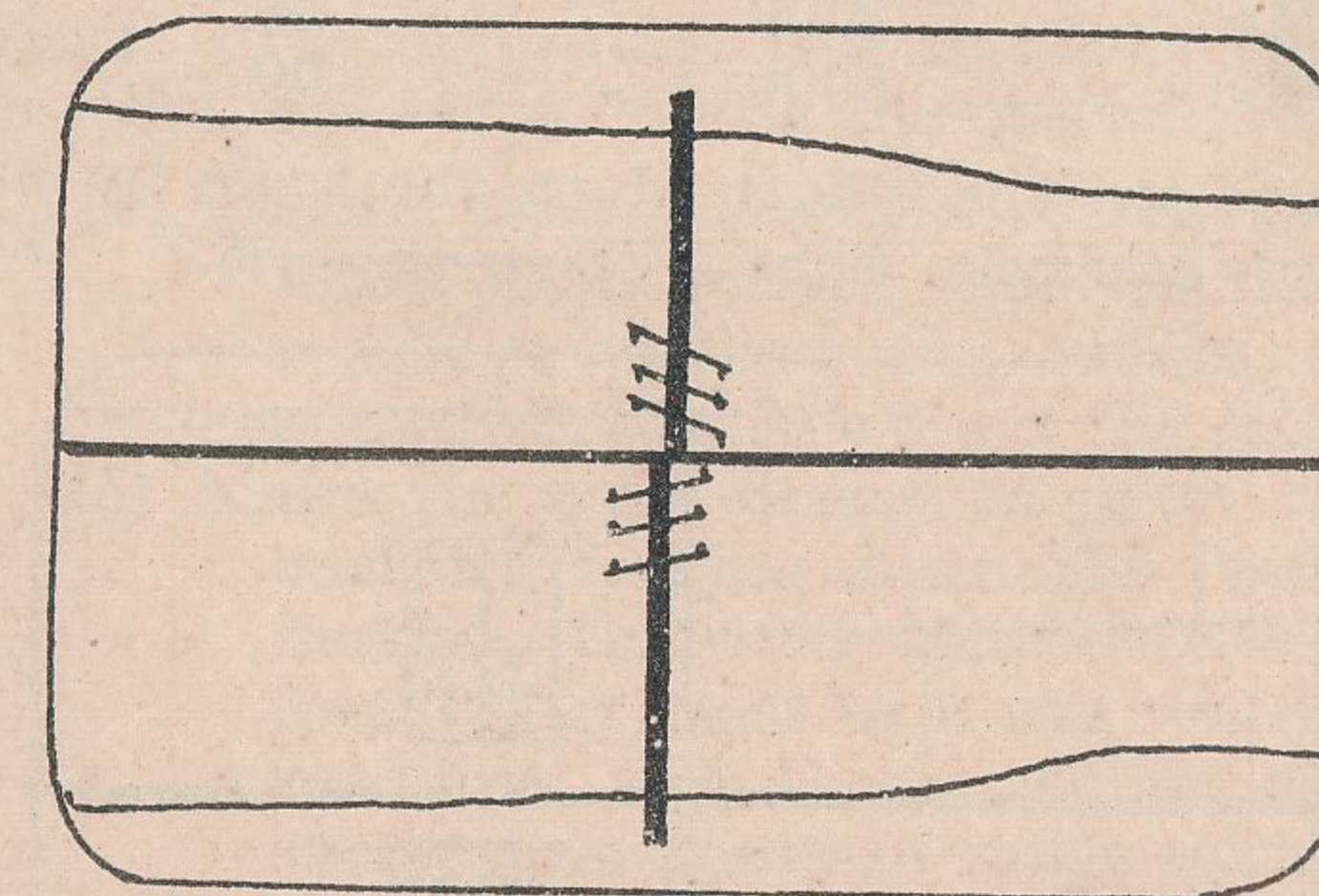


Fig. 1.—Incorrect coincidence.

Several coincidences must be made on the same object by bringing the images together from alternate sides, and it must be ensured that each coincidence is made without hesitation from the required side. The movement of the working head should be firm and steady, but not quick.

When coincidence is made on a straight line object, the range-finder should be turned so that the straight line cuts the dividing line at right angles. A straight line should be selected whenever possible.

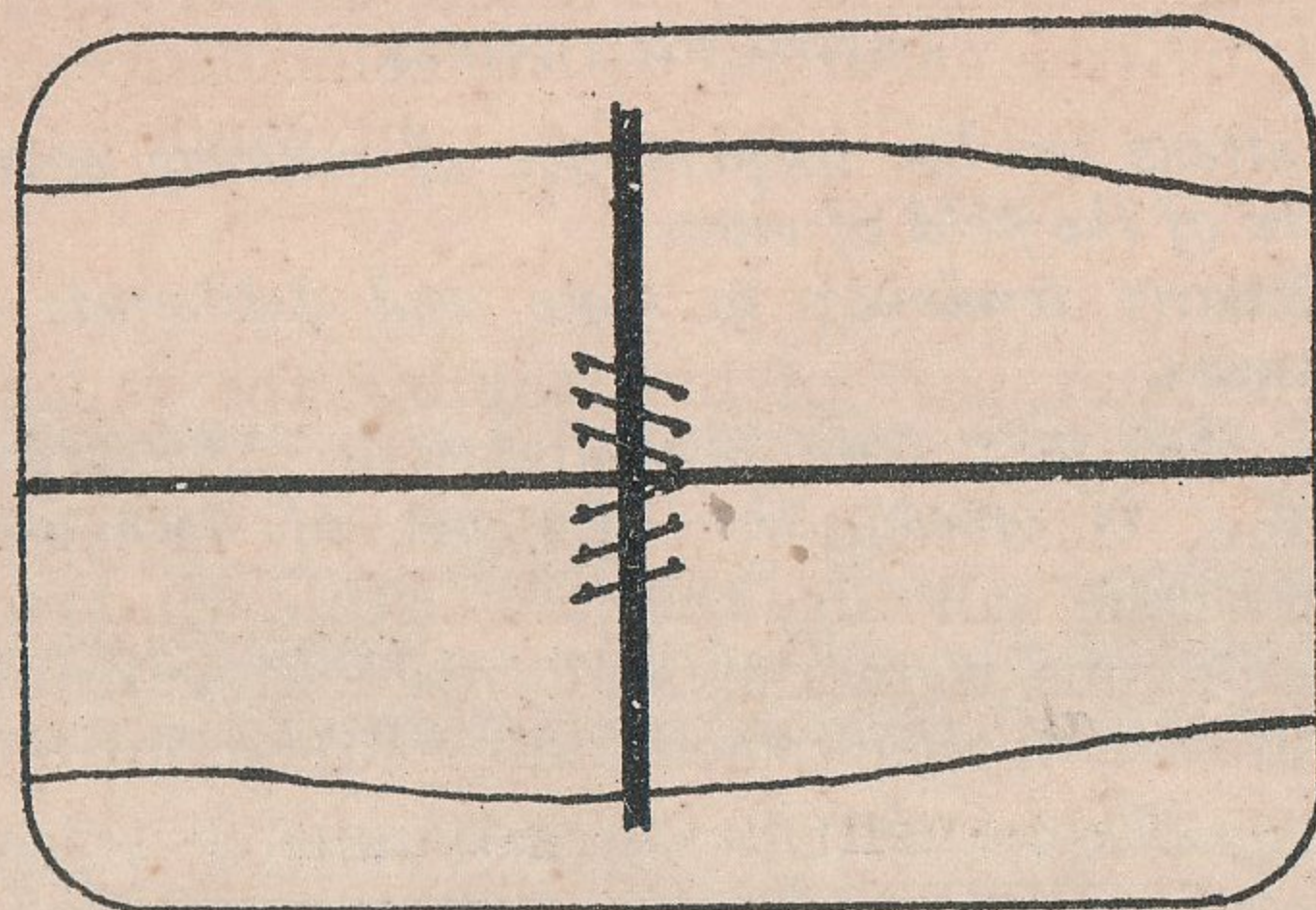


Fig. 2.—Correct coincidence.

**3. Reading the scale (Plate V).**—A coincidence having been made, the range scale window should be opened and the range scale read through the left eyepiece. The divisions on the scale vary in size from 10 to 100 yards. The graduations on the scale are:—

From	250 yards to 1000 yards	...	10 yards.
„	1000 „ „ 1500 „	...	25 „
„	1500 „ „ 2000 „	...	50 „
„	2000 „ „ 5000 „	...	100 „

The infinity mark is indicated on the scale by means of a line and an asterisk, thus: “——\*.” The range

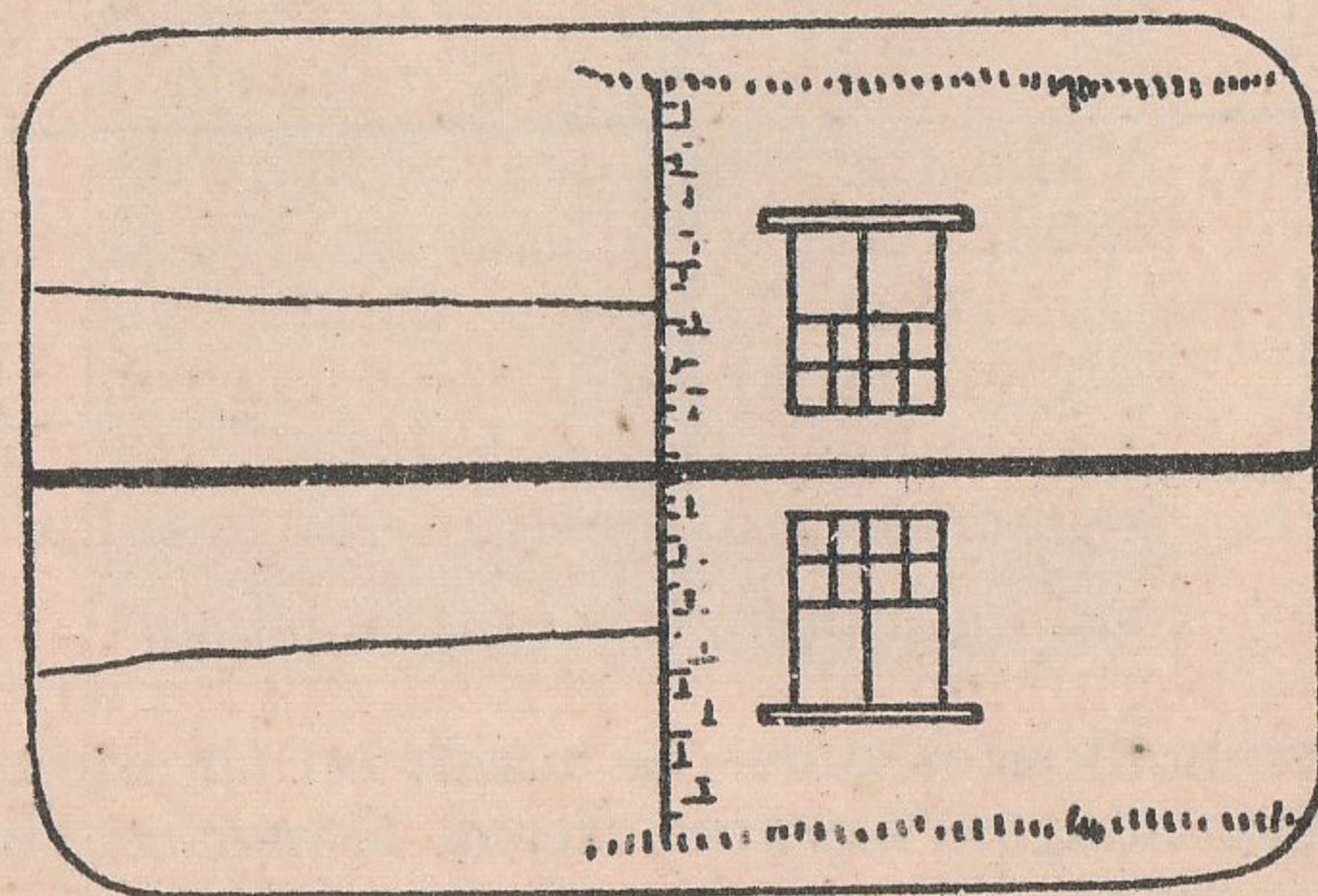


Fig. 3.—Correct coincidence. Note coincidence in centre of field of view. Wide object.

scale should be read as accurately as is permitted by the size of the divisions at the point in use. At short ranges it can be read to the nearest yard, and at longer ranges in multiples of 5 or 10 yards. The range scale window should be closed when a coincidence is made, as the light in the left eye will disturb the accuracy of the coincidence. The range scale can also be read through the front window for checking or testing the range-taker.

#### 4. Recording of readings.—

i. For the first part of his training the range-taker will be given a “reader,” who will record the readings taken. The reader will lie down facing the range-taker; he will raise the range scale window when each coincidence is made, and by looking in at the front window will check the reading called out by the range-taker. The two men being trained on each instrument will act alternately as range-taker and reader, and the reader as well as the range-taker will ensure that coincidences are made directly from alternate sides.

ii. Later in his training, the range-taker will be taught to write down his own readings as he will have to do in the field. It will be found difficult to remember from which side the last reading was taken, and practice will be necessary in some method of ensuring that readings are taken alternately from right and left. Also, it will be found that stopping to write down each reading will cause a considerable loss of time. The following two methods may be found helpful, the second being the quicker:—

(a) Before taking a series of, say, ten readings, mark each second line on the book. The readings against the marks must be for coincidences made from the right.

(b) Make the coincidences in pairs, one right and one left, writing down the two figures after making the two coincidences. It will be found that most men can remember the two readings, and there will be a considerable increase in speed of range-taking.

iii. Every reading taken, except the trial coincidences at the beginning of each series, will be written down in the book of the range-taker, either by himself or by his reader. No estimate of a range will ever be given unless the readings have been written down, added up and divided by the number of readings.

## SECTION 8.—ADJUSTMENTS

### Lesson 5.—Adjustment of halving

(Figs. 4, 5 and 6)

#### *Instructor's Notes*

*Begin the lesson indoors with diagrams of correct and incorrect halving and method of adjusting.*

*Outdoors, practise with straight-lined objects and compare results with flat-topped objects and crests.*

*The clicking system in the halving adjustment may not permit of an exact halving. Any man's halving may be very slightly different from the instructor's.*

It will sometimes be found that the same points of each image do not touch the dividing line together, and a coincidence cannot be made. By turning the halving adjusting head, however, the upper image can be made to move up and down in the field of view and this error corrected.

To correct the halving:—

- (a) Look through the instrument at the selected object and bring the bottom image near to, and parallel to, the dividing line, *i.e.* leaving a thin sky space between it and the line.
- (b) Turn the adjusting head until the top image shows the same amount of space between it and the dividing line as the bottom image. By turning the adjusting head clockwise, the top image is raised and, counter-clockwise, lowered.

The halving is most easily checked and adjusted on a flat-topped object or a crest, and this must be done whenever the instrument is set up for taking ranges. If the halving is not in adjustment, there will be considerable errors in the ranges taken, particularly in ranges to curved or irregular objects.

### Lesson 6.—Coincidence adjustment

#### *Instructor's Notes*

*The range-taker will be taught to work out his mean deviation and accuracy figure for each series taken on a known range during the day. The range-taking calculator or the table in Appendix IV may be used normally, but each man must be able to divide his mean deviation by  $r^2$ , in case he is without the table or calculator in the field.*

*The range-taker will then be taught to work out his mean*

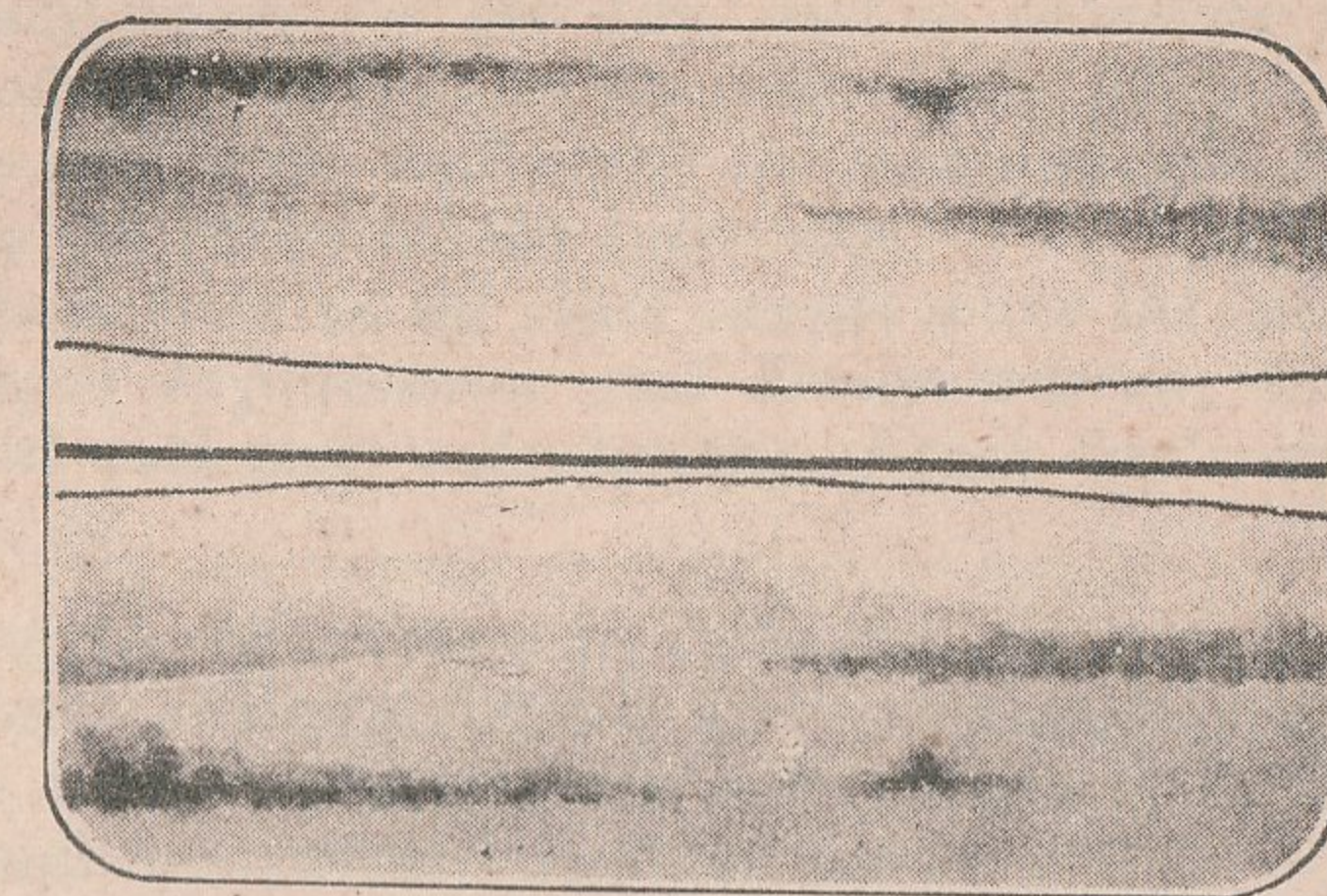


Fig. 4.—Halving incorrect. Top image too high.

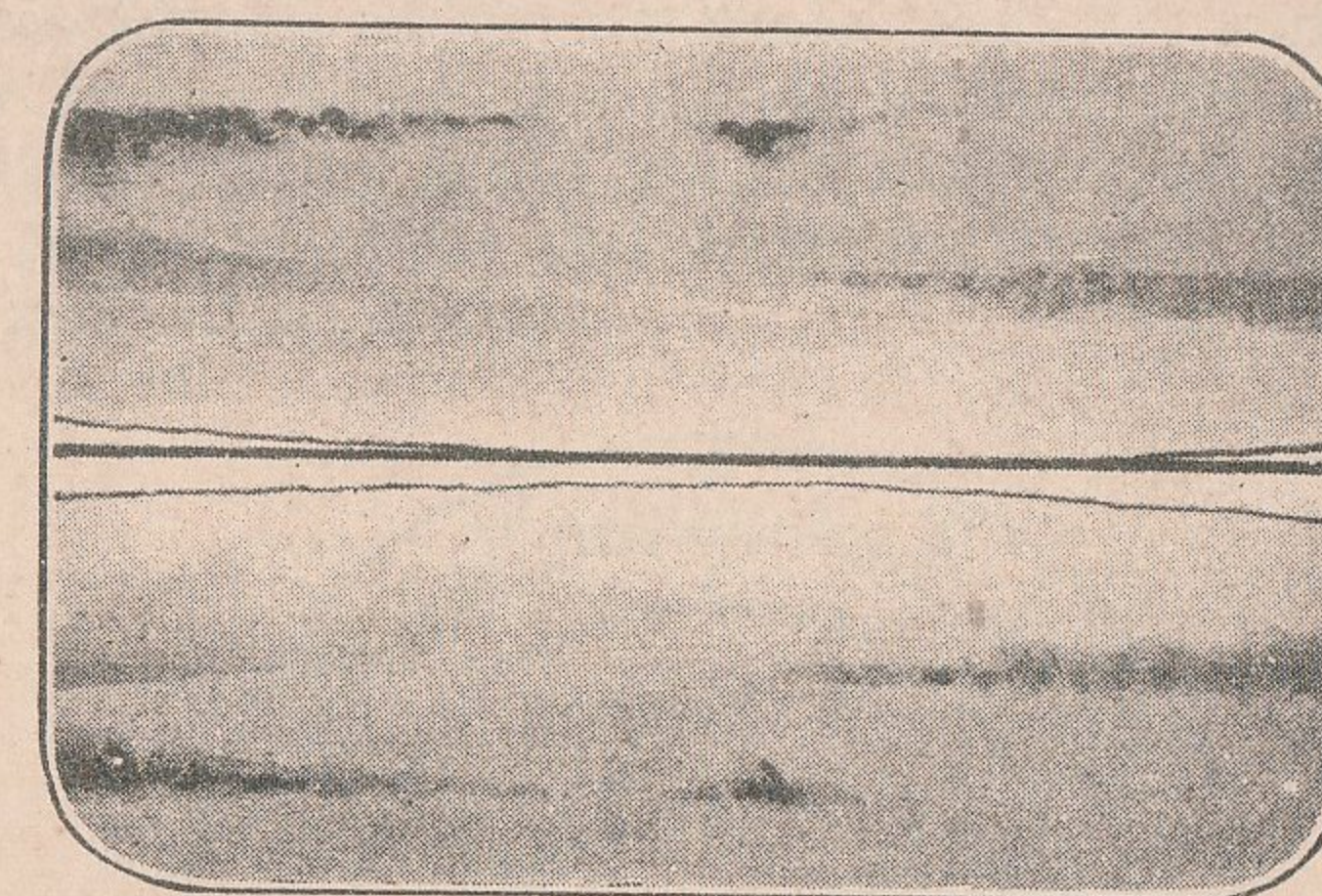


Fig. 5.—Halving incorrect. Top image too low.

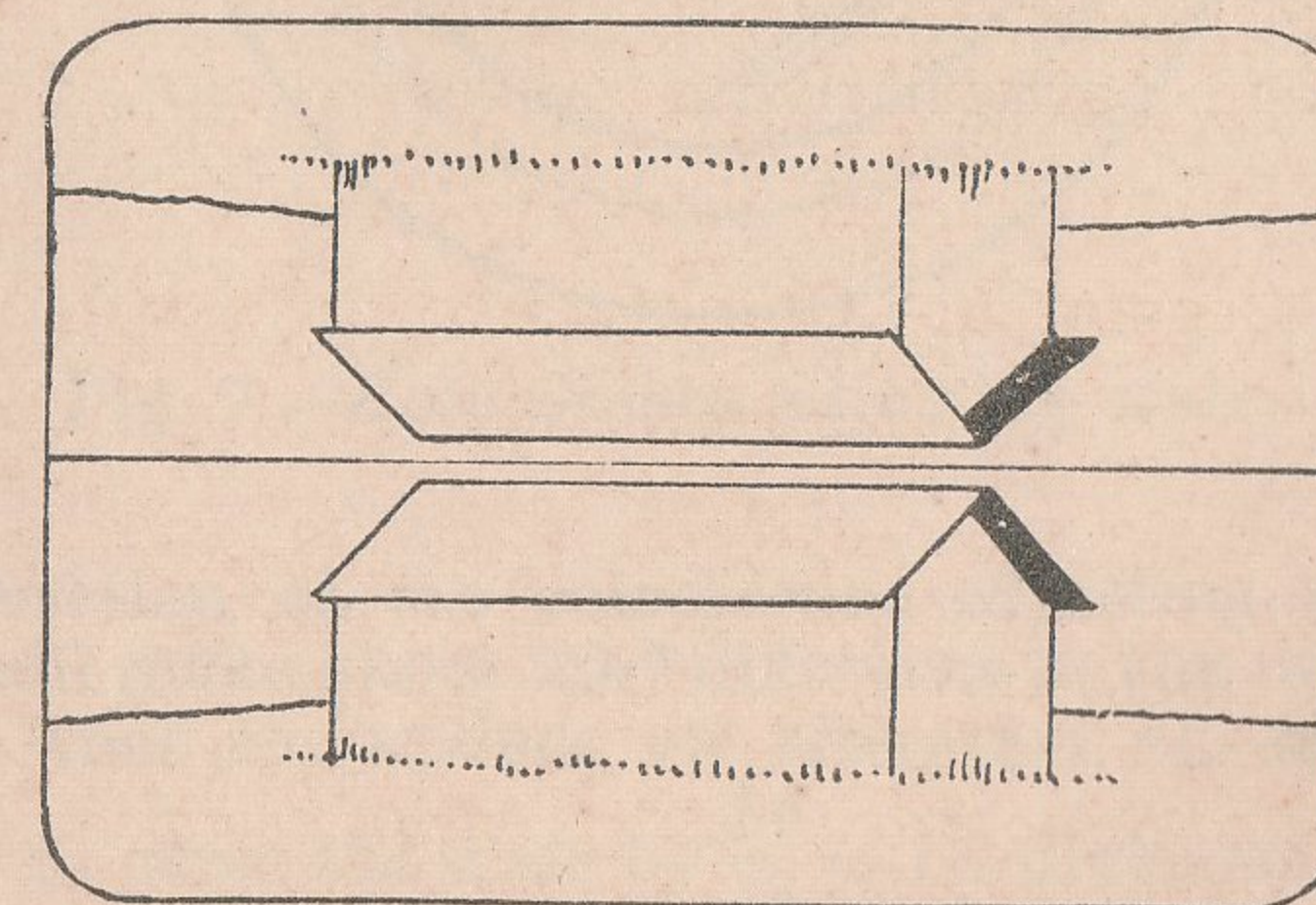


Fig. 6.—Halving correct.

the **right**, and to **lower** it, to the **left**. In recording the present reading on the scale it is necessary to describe the setting when the scale is looked at the right way up; with a scale on the bottom of the window the range-taker would look over the top of his instrument.

## Lesson 7.—Known range method of adjustment

### *Instructor's Notes*

*Explain that either an unknown instrument, or their own instrument, can be adjusted accurately for the conditions of the day, if a known range is available.*

*Ensure that the known range fulfils the requirements, and that the instruments are placed on the actual point from which the range has been measured, or within 12 yards on a line at a measured right angle to the range.*

### Requirements of a known range for adjustment

A range to be used for the adjustment of the instrument must be known to within  $r^2$ . Details of methods of finding these ranges and of calculating their accuracy are given in Appendix III.

The point to which the range is known must be a clear straight line object, and it is an advantage if it is on a skyline.

The range must not be a short one, and it should, if possible, be between 2000 and 3000 yards.

Given these conditions, a known range is preferred to infinity, because the range-finder is being adjusted at a range nearer to those which it will be required to measure.

In adjusting an unknown instrument, the range scale will first be set at the true range, and one coincidence made with the coincidence adjusting head, thereby ensuring that the ranges in the initial series will not differ widely from the true range.

**Procedure.**—The method of adjustment is as follows :—

#### *Method*

#### *Example*

##### 1. *Test.*

Take a series of ten readings and work out the accuracy figure. If this is  $5r^2$  of the true range, or less, the instrument is in adjustment. If this exceeds  $5r^2$  of the true range, the instrument requires adjustment.

T.R.	2147 yds.
M.O.R.	2073 „
M.D.	minus 74 „
	or minus $16r^2$
∴ Instrument requires adjusting.	

##### 2. *Adjust.*

If the accuracy figure is more than  $5r^2$  of the true range, adjust by turning the coincidence adjusting head to compensate the error (see Lesson 6, para. 2, page 19).

$$20r^2 = 1 \text{ division.}$$

$$1r^2 = \frac{1}{20} \text{ division.}$$

$$\therefore -16r^2 = -\frac{16}{20}$$

$$= -0.8 \text{ division.}$$

The coincidence adjusting head must therefore be turned to the **right** 0.8 division from previous setting.

If it had been at	It would be moved to
R. 3.4	R. 4.2
L. 2.6	L. 1.8

##### 3. *Check.*

Take a further series of ten readings and work out the accuracy figure to check the new adjustment.

T.R.	2147 yds.
M.O.R.	2163 „
M.D.	plus 16 „
	or plus $3\frac{1}{2}r^2$ .

∴ Instrument is now in adjustment.

4. Turning the coincidence adjusting head may alter the halving, which must therefore be checked and adjusted whenever the coincidence adjusting head is turned, before another series is taken.

5. A difference of  $20r^2$  per division may not apply accurately when large alterations are made on the coincidence adjusting scale, and so the instrument should be approximately in adjustment before the procedure given in this paragraph is carried out. If an approximate setting is not known, it can be found in this way: Set the range scale to the known range, and make one coincidence with the coincidence adjusting head.

6. Towards the end of his training, and in the field, the range-taker will be taught to work out his consistency (Sec. 10) as a guide to the reliability of the adjustment.

## Lesson 8.—Adjustment on natural infinity

### *Instructor's Notes*

*Adjustment on moon and stars will be practised as convenient, beginning with the moon by day, if possible.*

1. In the case of objects which are very far distant, such as the moon and stars, the range-finder records the range as infinity. Readings on the lath also give infinity. As infinity is marked on the range scale, the instrument can be adjusted on infinity in the same way as on a known range (see Lesson 7—Procedure).

The range-finder must never be directed towards the sun, or both the instrument and the man's eyesight will suffer.

2. Three divisions are marked above, and three below, the infinity mark on the range scale. Readings are noted as plus or minus from the infinity mark, and the mean calculated by dividing the difference of the pluses and minuses by 10. This gives the M.O.R. in divisions, and, as each division is  $10r^2$ , the accuracy figure is ten times the M.O.R.

	plus	minus	
		0.8	
	0.6	0.4	
		1.0	
	0.2		M.O.R. — 0.16
	0.8		
	0		M.D. — 0.16
		0.2	
	0		Accuracy
		0.8	figure — $1.6r^2$

3. The moon.—When the moon can be seen by day, it is a very good object for adjustment, because, in addition to the advantage of having daylight to work by, the range-finder is much nearer to the temperature at which it will normally be used.

In making coincidence on the moon, it is essential that halving be correctly adjusted, because on the curved edge an error in halving will make a considerable error in range; also particular attention must be paid to halving, because it is unlikely that an error will be noticed when there is nothing in the field of view but the moon itself. Halving can be adjusted on the top edge of the moon. Coincidence must be made on the clear outside edge of the moon, and not on the indefinite edge of a moon that is not quite full (Figs. 8 and 9). If necessary, the range-finder will be tilted so that a portion of the clear edge is at right angles to the dividing line.

4. A star.—In adjusting on a star, the astigmatizers must be used. Raising the astigmatizer lever causes both images of the star to become vertical lines, and coincidence is made much easier.

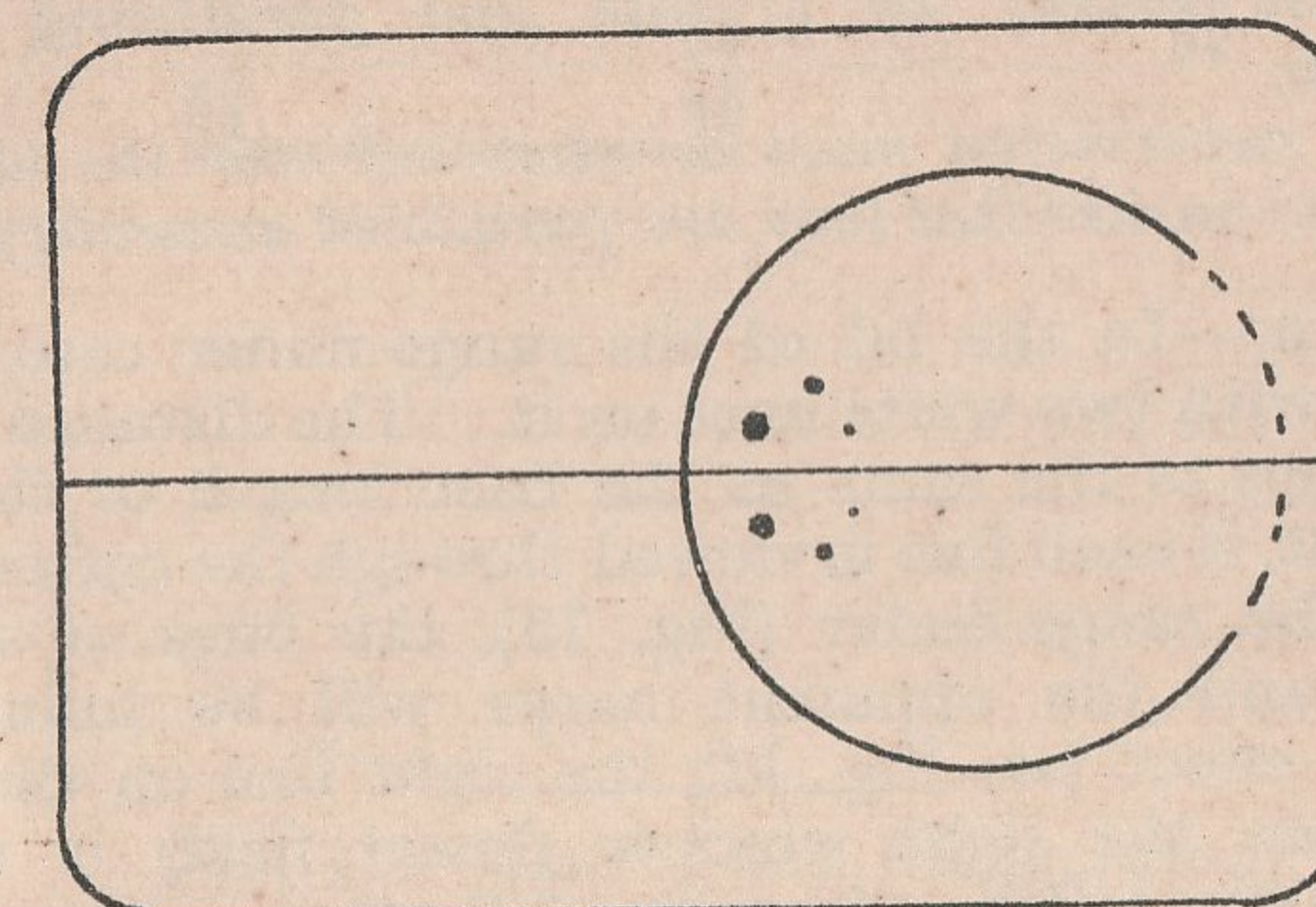


Fig. 8.—Correct coincidence on full moon. Note coincidence in centre of field of view.

Adjustment must not be made on a star unless the astigmatizers have passed the test laid down in Appendix II; otherwise they may not be accurate, and there will be an error in adjustment.

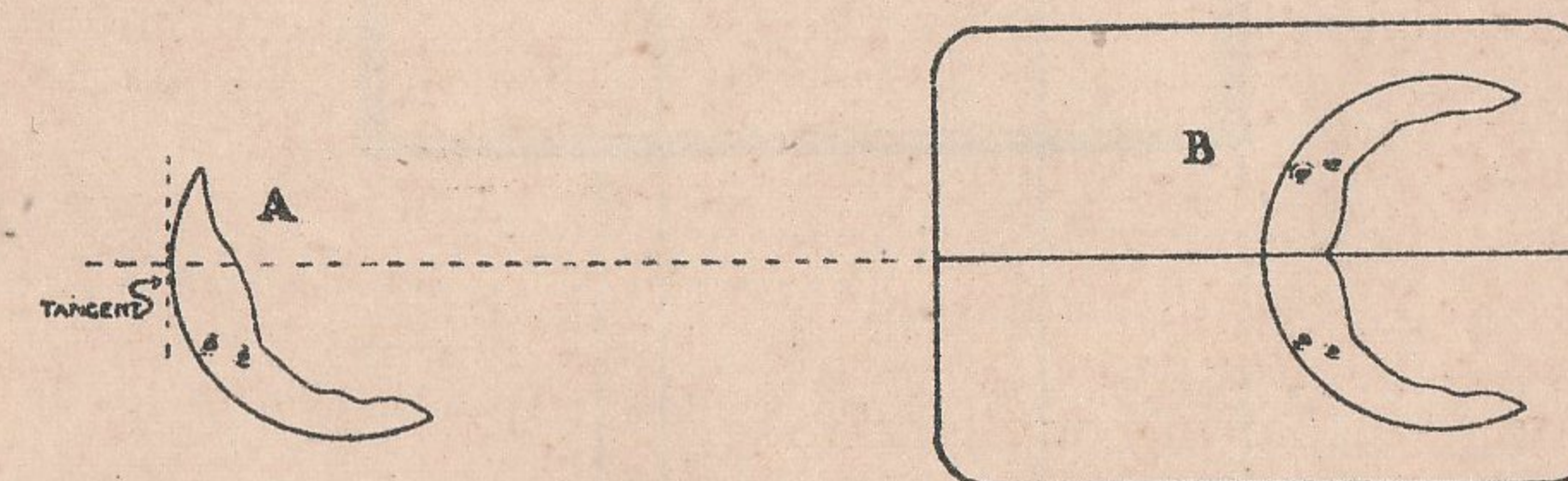


Fig. 9.—B showing correct coincidence on quarter moon. Note coincidence made with instrument horizontal, and dividing line at right angles to tangent shown dotted in A. A is the moon as seen with the naked eye. B is the same moon seen through the instrument.

Adjustment on the moon is preferred to adjustment on a star, because, even if the astigmatizers have passed the test, there may still be a small error in them.

## Lesson 9.—Adjustment on artificial infinity

### *Instructor's Notes*

*Practise setting up of lath and paralleling at short distances.*

*Close supervision must be exercised over the laying out of laths to ensure that they are paralleled accurately.*

1. The lath.—In the lid of the range-finder case there is a metal lath with two white lines on it. The distance between these two lines is the same as the base length of the range-finder, so that, if each line is viewed through the corresponding window of the range-finder (Fig. 10), the lines of sight will be parallel and the apparent range will be infinity. To produce this effect (see Fig. 11) the right line on the lath in the view from the right window (lower field) is made to coincide with the left line from the left window (upper field). The range will appear to be infinity.

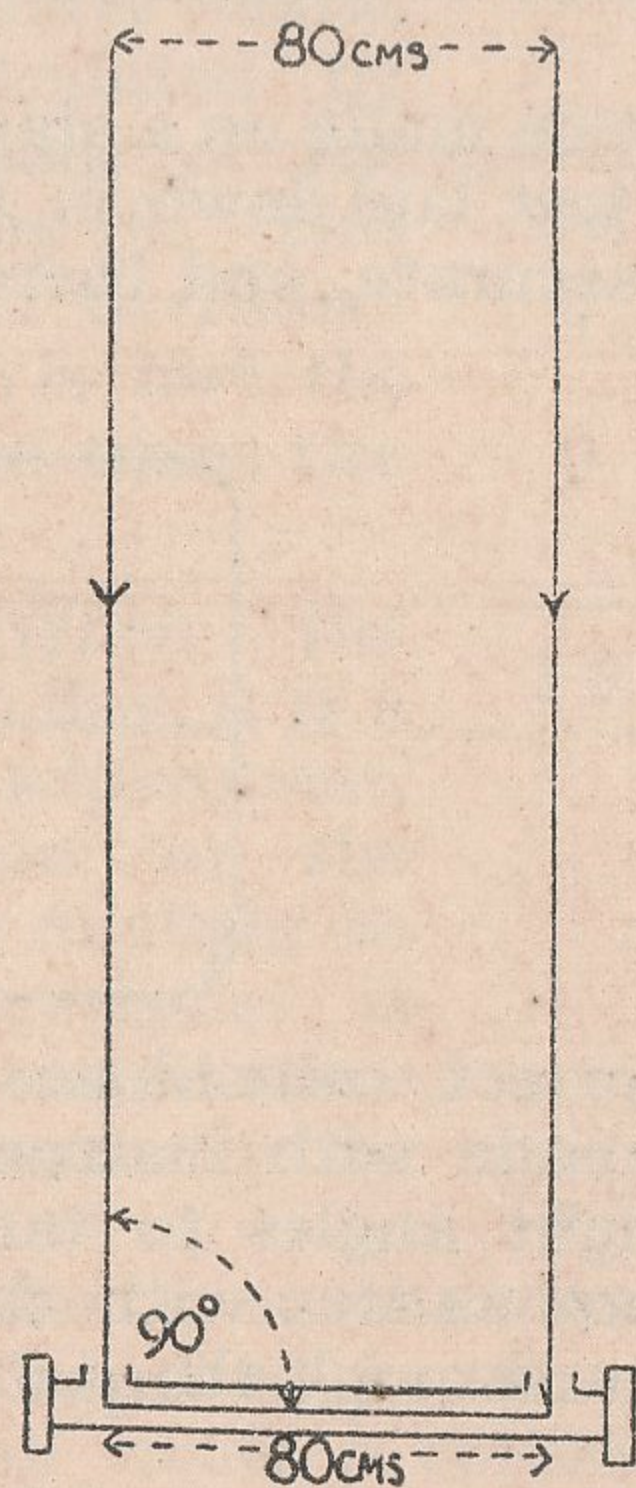


Fig. 10.—Diagram showing how artificial infinity is created.

2. The case must be set up at least 300 yards from the range-finder, so that any small error in the length of the lath will have little effect. The greater the distance the better, but visibility will not normally allow the case to be more than 500 yards.

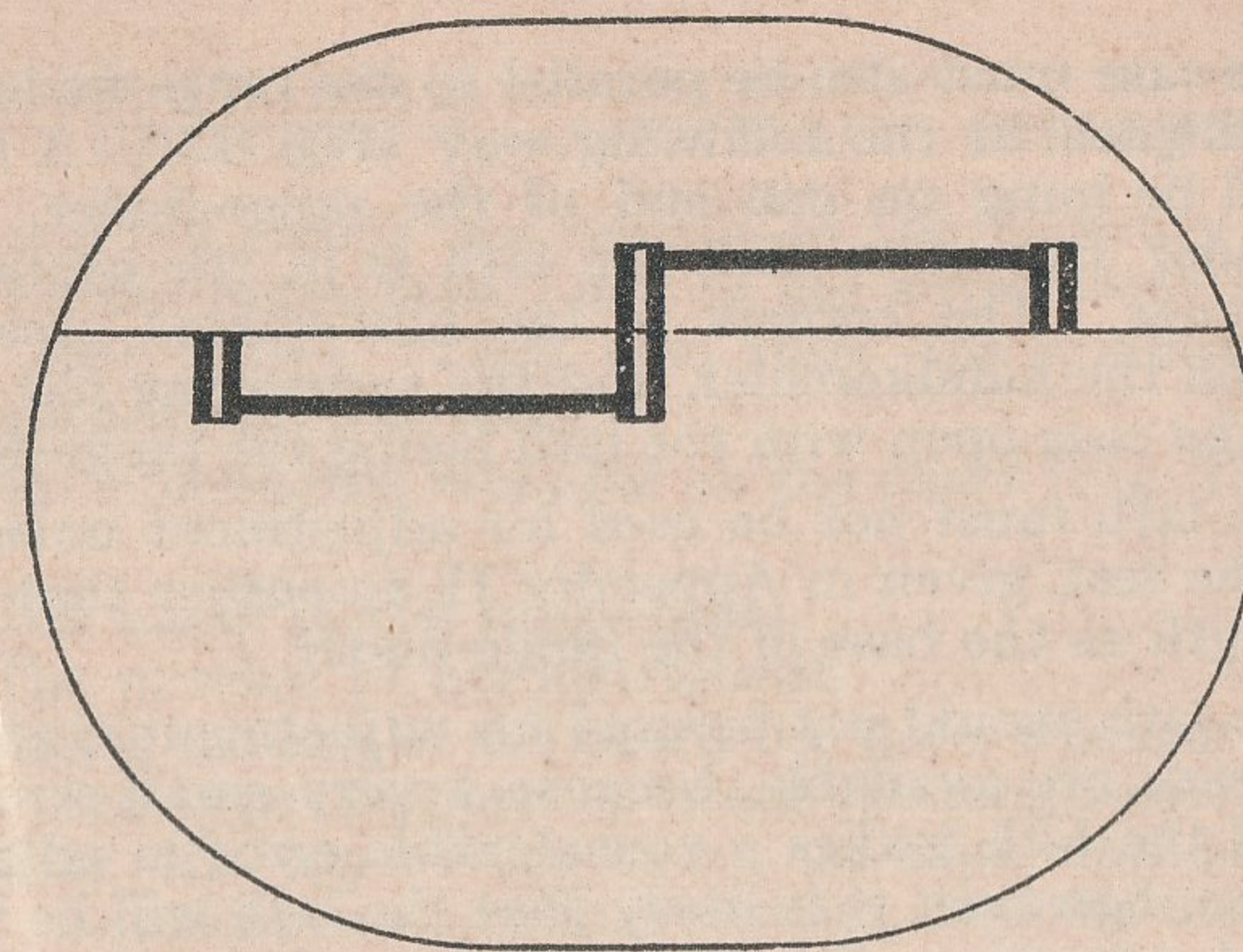


Fig. 11.—Size of lath exaggerated.

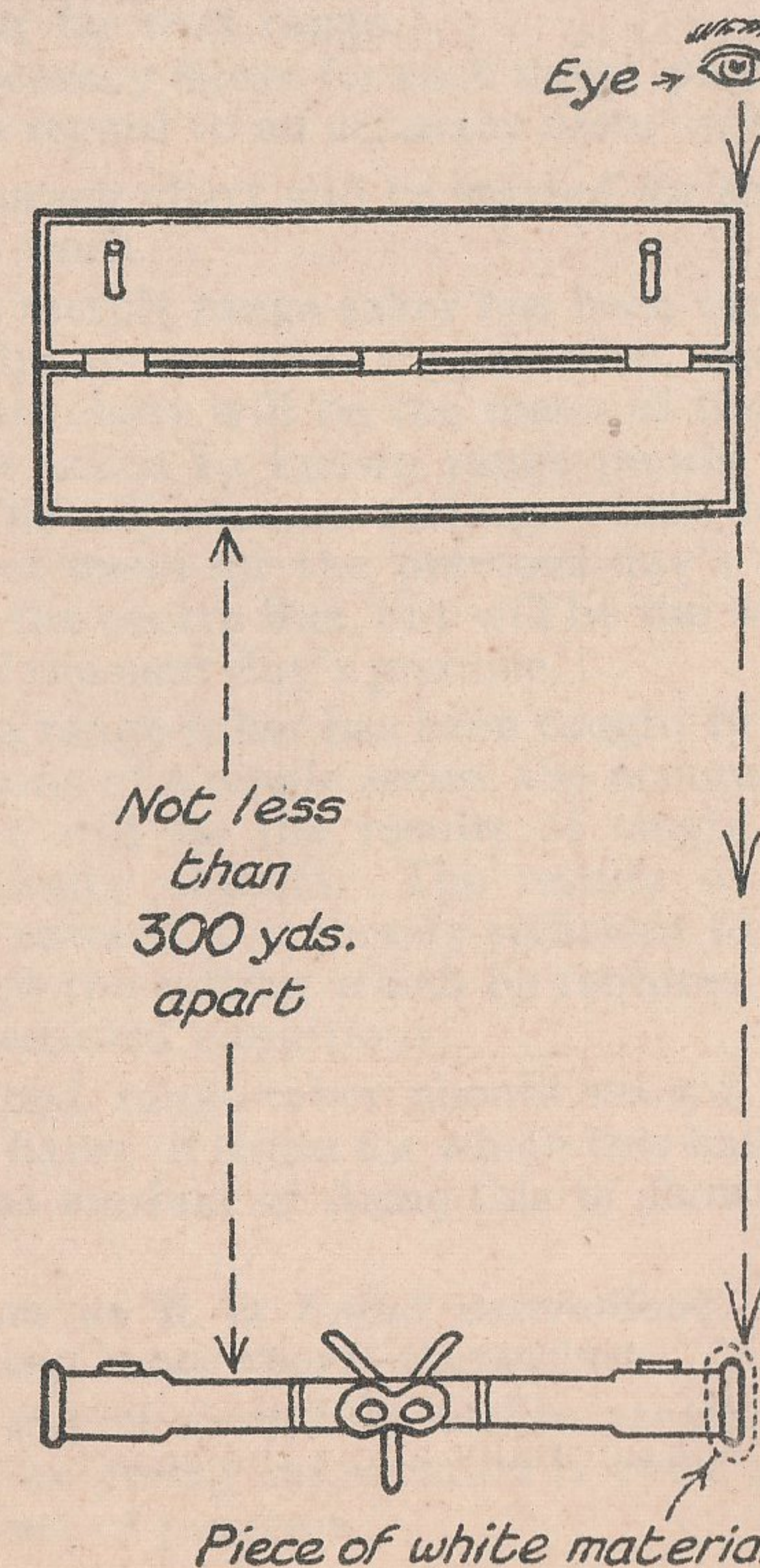


Fig. 12.—Diagram showing method of aligning case parallel to instrument.

3. The case must also be parallel to the range-finder, and it will be aligned in the following way (Fig. 12). A handkerchief will be hung on one end of the range-finder, and the range-finder turned so that the lath is in the centre of the field of view. The corners of the half-opened case will be aligned on the handkerchief, and the supporting rod dropped to hold the case open with the lath facing the range-finder.

4. The lath must not be used for adjustment unless it has passed the test, given in Appendix II, to ensure that it is the same length as the base of the range-finder.

5. The lath should not be used for adjustment if any of the other means are available, because a very small error in the length of the lath makes a considerable error in adjustment. On service, however, it is likely that the lath will be the only means of adjusting the instrument, and it is sufficiently accurate if it has passed the test.

## SECTION 9.—ACCURACY CHARTS

1. Accuracy charts are records of the accuracy of ranges taken by the range-taker, and of the adjustment he used to obtain each range. They also show the conditions under which each range was taken.

2. The information recorded on the chart (Fig. 13, page 28) is :—

- i. The name of the range-taker.
- ii. The number of his instrument.
- iii. Along the foot of the chart, the date, weather conditions and type of object to which the range was taken.
- iv. Near the top of the chart, on each vertical line, the coincidence adjustment setting used for that series.
- v. Along the centre line of the chart, the coincidence adjustment setting which would have given a perfect result for that range.
- vi. The accuracy figure for each range, plotted in its position with regard to an accuracy scale on the left.

3. An accuracy chart will be started for each man after the fourth day's work.

4. Until a recruit range-taker has been taught to adjust his instrument by means of a single series, the accuracy figure plotted on his chart will be the mean of the accuracy figures of all ranges taken to known range points during one day's practice. The adjustment setting, which would have given him a perfect mean for the previous day's work, will not be recorded on the centre line, but will be the setting used during the whole of the next day's practice.

5. When a range-taker has been taught to adjust his instrument by means of a single series, the accuracy figures plotted on his chart will be the results of single series on known range or infinity objects. The results of all ranges taken need not be entered, but merely sufficient to show his progress and to record the setting which he requires on his instrument under the recorded conditions.

6. A trained range-taker should record on his chart the consistency figure of series for which this has been worked out. A convenient method of doing this is shown on the specimen chart.

7. As soon as it is found convenient, the men may be taught to keep these charts themselves.

8. These charts should be readily accessible to the men, as their value in giving information is even greater than their value as a test of progress.

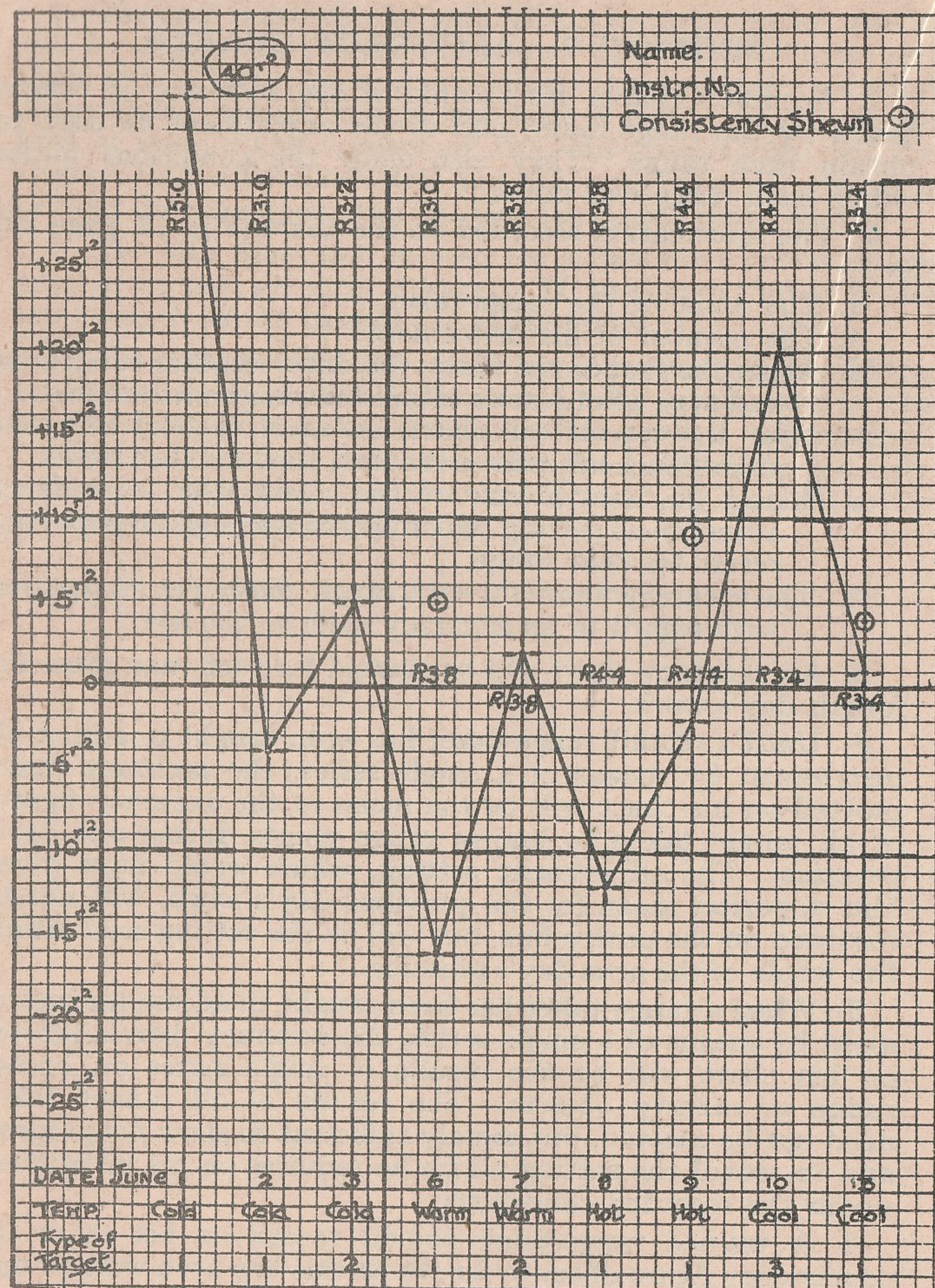


Fig. 13.—Accuracy chart.

NOTE:—The types of target are numbered to represent:—

1. Easy straight-edged objects.
2. No definite straight edge (bush, bank, etc.)
3. Difficult service targets.

## SECTION 10.—CONSISTENCY

### Lesson 10.—Calculation of consistency

#### Instructor's Notes

Work out on the blackboard one or two examples on the yards and infinity part of the scale.

The class work out their own C.F. for some of their previous series.

Do not labour consistency. It is possible for a range-taker to be accurate although not consistent. However, it is probable that his accuracy will improve in line with his consistency.

No effort should be made to bring down the consistency figure of a man whose accuracy figure is satisfactory, because it is not desirable to encourage a man to try too hard to make every coincidence perfect. Each man should note the normal consistency figure with which he gets good accuracy.

When consistency figures are worked out for a series of which the accuracy figure is put on the man's chart, the consistency figure should also be plotted on the chart in the manner shown on the specimen chart.

1. Consistency is the "size of the group" of readings. When taking ranges in the field under bad conditions, if there is sufficient time, such as in defence, the range-taker must work out the consistency of his series to discover the probable accuracy of the result. Conditions may exist where the ranges he takes are unreliable, and he must know whether this is so or not.

It will be found that the normal consistency figure of a trained range-taker is about  $5r^2$  in good conditions. This may vary slightly with different men, the standard set being in accuracy and not in consistency. In bad conditions, however, the consistency figure and the accuracy figure will vary.

Any large variation in the consistency figure should warn a range-taker to suspect the accuracy of the series.

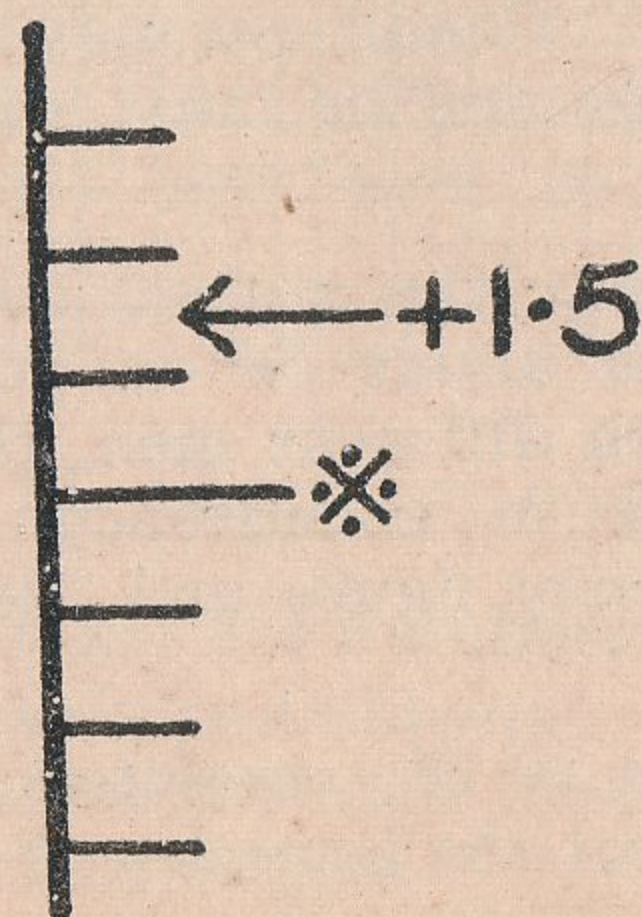
2. Examples of the calculation of consistency :—

Range scale		Infinity scale	
Reading	Residual	Reading	Residual
1850	11	—	0.8
1840	1	0.6	0.8
1880	41	—	0.4
1810	29	—	1.0
1840	1	0.2	0.4
1870	31	0.8	1.0
1850	11	0	0.2
1810	29	—	0.2
1800	39	0	0.2
1840	1	—	0.8
10)18390		plus 1.6	10)4.8
10)194		minus 3.2	
1839	19.4		0.48 (Mean residual).
(M.O.R.)	(Mean residual)	10)minus 1.6	
Consistency 19.4		—0.16 (M.O.R.)	
figure	$\frac{r^2}{6r^2}$	Consistency figure	$0.48 \times 10$
			$= 4.8r^2$

Notes on the infinity calculation.

(1) The M.O.R. is taken only to one place of decimals (in this case, — 0.2 for — 0.16) in calculating the residuals. This saves labour, and is sufficiently accurate.

(2) If any difficulty is experienced in calculating the difference between the M.O.R. and readings with the opposite sign, or infinity itself, a diagram should be drawn of the range scale with an arrow at the position of the M.O.R. The distance of the arrow from the position of each reading should then be apparent.



SECTION 11.—RANGE CARDS

Lesson 11.—Construction of range cards

Instructor's Notes

The construction of range cards can be practised in three ways :—

1. Give the class figures from which to construct a range-card indoors.

2. Mark on a sand table the range-taker's position and six points which are required on a range-card. Each range-taker will measure the ranges by a ruler or a scale on the side of the table, judge or measure the angles, choose his own setting ray, and make out the range card form and range card.

3. Give six easy objects outside. Each man will take the ranges and make out his range card form and range card. The ranges need not be known ranges, but any range which differs greatly from the average to that point should be investigated. No time limit should be given at first, but any waste of time should be discouraged.

1. Detailed description of range cards and the method of recording ranges on the card are contained in Pamphlet No. 2 of this series.

2. Before completing the range card, range-takers should prepare and complete the form shown below. From this detail the range card can be constructed under cover.

Setting Ray.....

Object	Range	Degrees	
		Right	Left

Name.....

Unit.....

## SECTION 12.—TAKING RANGES UNDER DIFFICULT CONDITIONS

### Lesson 12.—Difficult objects

#### *Instructor's Notes*

*Give three or four difficult targets. When the class have taken the ranges, question them as to the methods used and discuss the best.*

1. Where no portion of the object to which the range is required is a straight line, it will not be possible to make coincidence as described in Sec. 7. In this case it will be necessary to choose a distinct mark on the object, and bring the two images of that mark so that they touch the dividing line in the centre of the field of view, without actually cutting the line (see Fig. 14). A series of "coincidences" will be made in this way alternately from right and left as before. The more accurate the halving adjustment the easier and more accurate will be the making of coincidences. Accuracy will not be so good as when a straight line is available, and, where the point is not very distinct, the consistency of a series should be worked out to discover whether the range is reliable or not.

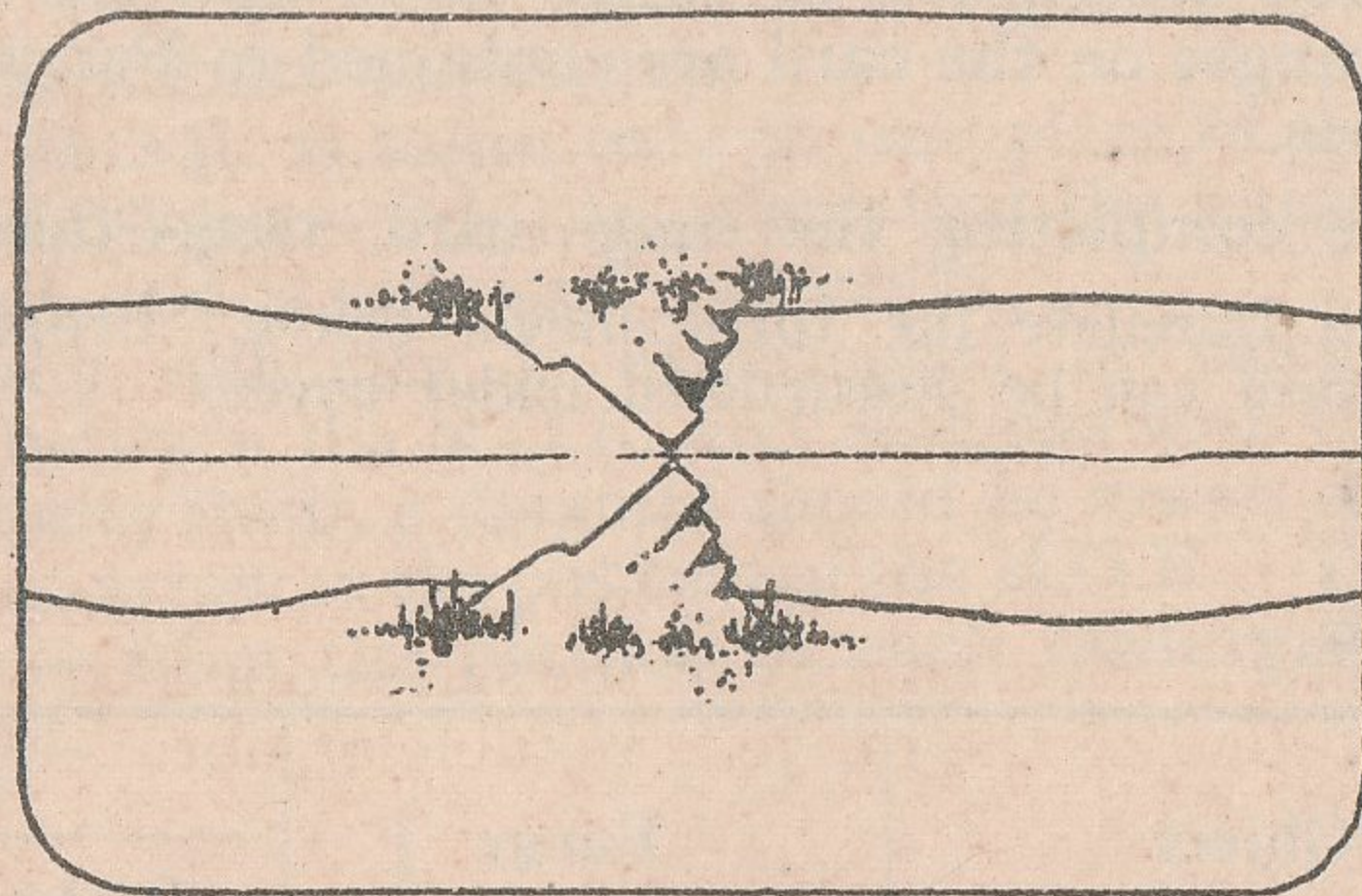


Fig. 14.—Showing coincidence by symmetry of images.

2. A moderating glass is provided in the right eyepiece, which may be used to moderate very bright light, or to make the view clearer in mist. The range-taker may use it whenever he likes, and, if the light is unpleasant, he should try the glass to see if it helps. The glass has no appreciable effect on accuracy, but the more comfortable the conditions are for the range-taker the more accurate are his readings likely to be.

3. The astigmatizers must be used for adjustment on a

star, and for taking the range to a light at night. They will also be of assistance in taking the range to a light patch, such as a white stone, by day.

If the range is required to an object on which there is no definite point on which to make coincidence, the astigmatizers should be tried. It will sometimes be found that a mark on the object is drawn out into a light or dark line on which it is easy to make coincidence, but care must be taken that the line is formed by a mark on the required object, and not by some mark nearer or farther away than the object, which might appear to be a line crossing the object required.

### Lesson 13.—Taking ranges in rain and shimmer

1. Rain does not affect accuracy unless it is entering the front windows of the instrument. Under these conditions it is impossible to obtain a reliable range, and the instrument must be protected by going under the lee of a haystack or into a shed, or by improvising some form of shelter.

2. Shimmer is the rising of hot air from the ground. It causes the two images to vibrate independently of each other, and it becomes very difficult to make coincidence.

When images, owing to shimmer, are not stationary, the only method of judging a coincidence is by deciding that the upper image moves the same amount to the right and left of the lower image.

Shimmer occurs mainly when the line of sight is close to the ground on a hot day. It may be greatly reduced, particularly when caused by a near crest, by raising the instrument above ground level, on top of a post or vehicle, or by taking the ranges from the window of a house or the top of a haystack.

Reasonable results will normally be obtainable, but in some cases it may be impossible to obtain a reliable range. Where there is doubt, the consistency of the series must be worked out to discover whether the range is reliable or not.

### Lesson 14.—Taking ranges to moving objects

1. It is impossible to obtain a series of readings to a moving object, as the actual range alters between readings. Also, it is impossible to obtain a reliable range unless a series of readings has been taken.

2. The range must therefore be taken to some point near to which the moving object will pass, and the fire controller must be given this range in time to allow him to give an anticipatory fire order on this point. Ranges already on a range card may be available for use in this way.

3. If it is impossible to obtain the range to a point ahead of the moving object, as would be the case with an object at sea, each reading taken to the object itself will be called out to the fire controller or to an assistant. A reliable range will not be obtained, but to some extent the readings will check each other, and a rough estimate of the correct range will be obtained.

## SECTION 13.—CONCEALMENT AND FIELD DUTIES

### Lesson 15.—Positions and concealment

#### *Instructor's Notes*

1. Show different positions, and practise class.
2. Practise class taking ranges from different pieces of cover, insisting that the steadiest position possible is always taken up.
3. Class take the same range both lying and in some other position, and work out the consistency of the two series to compare their probable accuracy.

1. The range-finder is very difficult to conceal, because it must be set up so as to give a clear view from both windows, and, being a straight object, it is easy to see.

The range-finder can sometimes be concealed behind a bush or a tree, with one window looking round each side. When this is not done, the background must be considered, and skylines particularly avoided. The straight line of the instrument must be broken, whenever possible, perhaps by placing a piece of bush in front, and at times it may be necessary to use the range-finder at some distance from the section position.

2. A lying position should be used, if possible, because it is the steadiest and most comfortable. If this is not possible, the instrument may be used sitting, kneeling or standing, but accuracy will be less, and, where there is doubt, the consistency of the series must be worked out to ensure that it is reliable. Whichever position is used, the stand of the range-finder and the elbows of the range-taker must be rested, even if only on the range-taker's chest, and the instrument or the man's body or leg must be rested or steadied in the best possible way.

### Lesson 16.—Field duties

#### *Instructor's Notes*

*Explain duties in various roles and question class. Arrange exercises without troops, instructor acting as section commander, one of the class as orderly, etc., while the remainder of the class watch and criticize. Stop the exercise where necessary to bring out the points required. Exercises should be carefully worked out beforehand, and should include all the roles of a machine gun platoon.*

1. The field duties of the range-taker are given in Pamphlet No. 7 of this series. They are taught in headquarters training, but the range-taker should have a sound groundwork before he does headquarters training, and instruction must therefore be included in range-taking training.

2. The range-taker is responsible for the following :—

- i. Checking the adjustment of his instrument at frequent intervals by the best means available.
- ii. Ensuring that his astigmatizers and lath are in order, by putting them through their tests occasionally (Appendix II).
- iii. Writing down all series in such a way that they can be checked afterwards, or the number of readings increased.
- iv. Knowing or asking the time available to take ranges, so that he can decide on the number of readings to take.
- v. Never giving a range unless he has taken at least four readings, and found the mean on paper.
- vi. Warning the fire controller when he suspects that a range is not accurate, because of difficult target or conditions, and calculating the consistency so that he can give some idea of its probable accuracy.
- vii. Giving all ranges as he obtains them. He will not give them to the nearest 50 yards, and will not correct them for his distance from the fire controller unless specially ordered.
- viii. Reminding the fire controller to correct ranges for the range-taker's distance from the gun position, when necessary, by giving the range as "so many yards from here."
- ix. Observing fire, giving the fire controller the distance in yards of strike from the target. If strike is not visible, taking the range to the target.
- x. Making out a range card whenever he has time, and giving it to the fire controller. This is an exception to vii., above; the ranges on the card will be corrected for the position marked on the bottom of the card, which will normally be the gun position, but they will still be given as accurately as possible, not to the nearest 50 yards.

3. The range-taker should be practised in indicating objects both as seen by the naked eye and as seen through his instrument, the latter to be recognized by the fire controller using field glasses.

In certain circumstances it may be advisable to send the

range-taker under cover, after he has obtained the necessary ranges, both to protect a valuable man and instrument, and to hide the instrument from enemy observation. The instrument is, however, a very good telescope, and it may sometimes be an advantage to use the range-taker as an observer when no more ranges are required.

Whenever possible and especially to observe fire, some knowledge of beaten zones is required, and the range-taker should be given every opportunity of practising observation of fire.

The section commander is at all times responsible for detailing the points to which he requires the range taken by the range-taker, as the section commander is the one who is in the best position to do this; he is more in the tactical picture.

A range-taker should, however, take every opportunity, when not otherwise required for observation purposes, etc., to improve the arc of fire by taking ranges to other objects.

4. The range-taker must work with the fire controller as a team. He should know what orders to expect, and what his duties will be. A brief summary of his duties is :—

- i. *Attack*.—Takes ranges while the section commander selects gun and control positions, but may be some distance from section area. He must return in time to give range to first target when required, and then may be ordered to complete range card, to observe fire, or to go back under cover.
- ii. *Defence*.—Construct a range card. An extra range card may be required for riflemen from the alarm post. Both cards to be improved and checked frequently. He will have to take his place on the N.C.Os.' or men's duty roster.
- iii. *Withdrawal*.—Longer ranges are required at first. The range-taker may have to select points for his own card, when sent back to an intermediate position.
- iv. *Indirect fire*.—One range-taker is required by the platoon commander, the other by the senior section commander at the gun position.

## SECTION 14.—RANGE-TAKERS' TESTS

### General

1. A trained range-taker should work to an accuracy figure (A.F.) of  $8r^2$  in good conditions, and in training he should seldom be above  $16r^2$ . On service, conditions are likely to be worse than in training, and an accuracy figure within  $25r^2$  will satisfy the machine gun fire control and safety rules.

An examination of each range-taker's accuracy chart will show whether he is normally within these figures, and, if he is, he is fit to undergo the annual test.

2. Two tests will be passed annually by each range-taker :—

i. *Test of elementary training.*—Each range-taker to be passed during the individual training period under company arrangements. The recruit range-takers should pass this test during their fourth week of training. A man may repeat the test until he passes.

ii. *Annual test.*—To be carried out annually under battalion arrangements during suitable weather.

Any man who fails to reach the qualifying standard may be re-tested at any time before the end of the training year. Should he then pass, he will be shown in the annual return as qualified.

3. Methods of obtaining known ranges are given in Appendix III. The work should be entrusted only to an officer who can calculate the degree of accuracy obtained. Whenever ranges are obtained by survey, the surveyor should state the maximum error in the ranges provided by him.

4. Ranges for tests should be taken from as sheltered a position as possible, the direction should not be towards the sun, and it is an advantage if the line of sight passes over a valley to avoid shimmer. It is advisable, if ranges are likely to be required for subsequent tests, that they should not become known to men undergoing tests.

5. Including the adjusting ranges, two ranges are required for the test of elementary training and three for the annual test. If newly surveyed ranges are not available, both tests may be conducted with falsified ranges. These falsified range tables are available in each battalion, and instructions for their use are attached to the tables. Alternatively, for the T.O.E.T. only, a N.C.O. may be placed in front of the range-taker under test to check his readings through the front range scale window.

In calculating values of  $r^2$ , sufficient accuracy is obtained if  $r$  is regarded as the range in thousands of yards to the nearest decimal place.

### Test of elementary training

#### 6. Part 1. Oral test.

About five questions will be asked on care and cleaning, methods of taking ranges and adjusting instrument, field duties, etc. The qualifying standard will be 60 per cent. and the man will be recorded as "pass" or "fail."

#### 7. Part 2. Practical test.

The man will be shown two good straight line objects over 1000 yards distant, in approximately the same direction. He will be told the true range to one of them. (The range should be known to within  $r^2$ .)

He will then adjust his instrument on to this point. When he claims that his instrument is correctly adjusted he will be required to find the range to the other point. (The range to this point should be known to within  $2r^2$ .)

The man will be marked as "pass" if his accuracy figure is  $8r^2$  or less and his time for finding the range is 10 minutes or less.

### Conduct of annual test.\*

8. Not more than 12 men will be tested at one time. A separate base may be used for adjusting instruments, if this has been surveyed. Each detail of 12 men should take about 50 minutes, or 35 minutes for details after the first if a separate base is used for adjustment.

9. The following stores are required for the test :—

Six directors.

About 30 yards of rope for each base.

Three stout pegs for each base to be marked.

One stop watch.

Record sheets, according to the number of men to be tested.

\* NOTE.—Not applicable to A.M.F.

10. From the centre of the base, which must be the marked and surveyed point, a right angle to the centre of the arc containing the targets is measured and marked with rope.

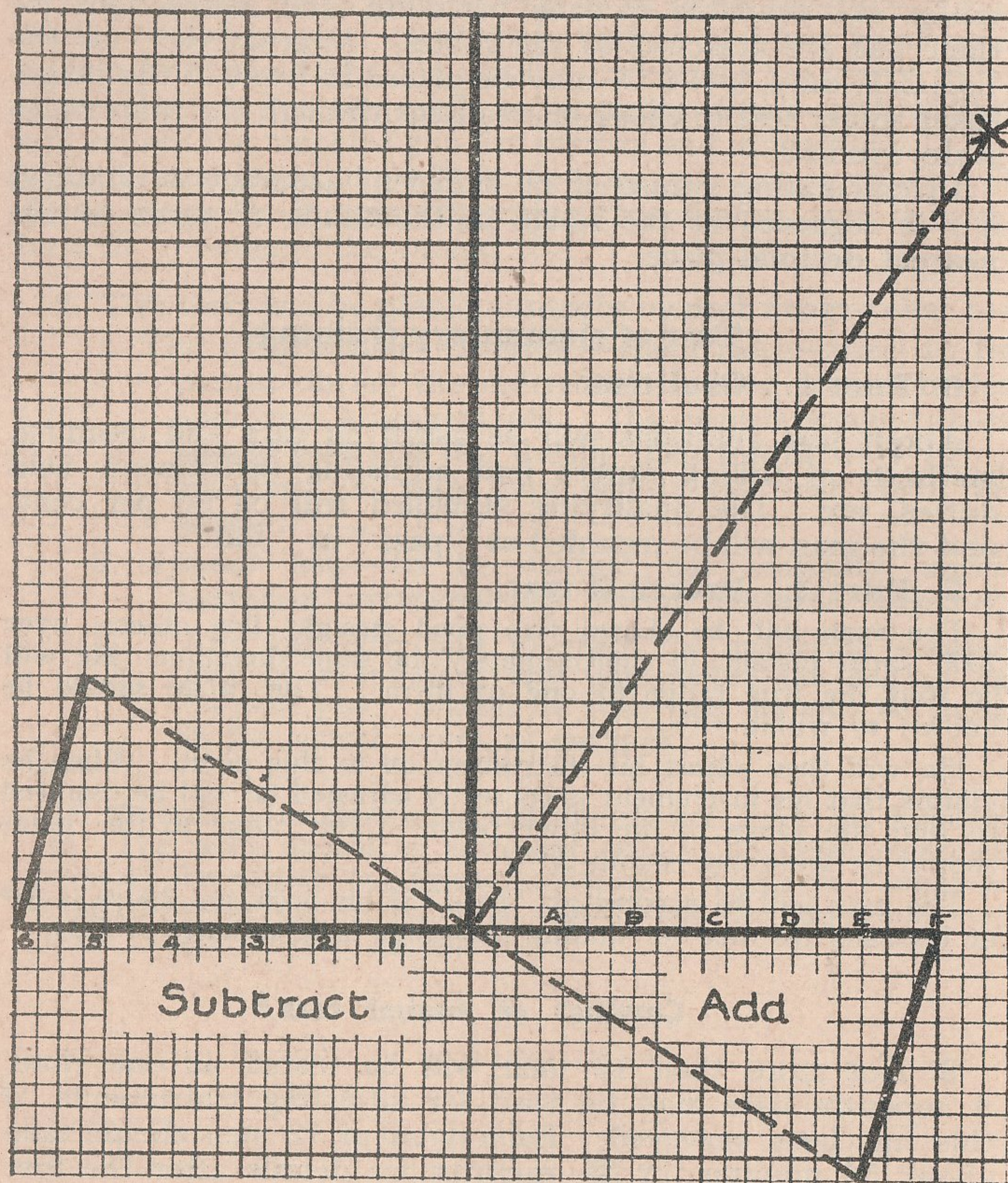


Fig. 15.—Calculation of allowances for objects outside  $4^\circ$  arc from line at right angles to centre of base line. These allowances will be added to or subtracted from the ranges obtained by the range-taker.

A length of tape is tied to the rope at each six feet from the centre to mark the position of each range-taker. Six positions are marked on each side of the centre peg. If a separate

base is used for adjustment, this is marked out in the same way, at right angles to the line to the adjusting point.

11. If any object used in the test is not within four degrees of the line at right angles to the centre of the base, then the range from each end of the base cannot be taken as being the same as the range from the centre, which is the surveyed point. Allowances will have to be made in the following way (Fig. 15): Mark from the centre of the base a line at right angles to each point which is more than four degrees from the centre line. Measure the distance from the end range-taker's position to that line, in the direction of the object. This distance must be added to, or subtracted from, the end range-taker's result before being entered on the record sheet. The correction will be the same for the two end range-takers, but in opposite directions, and will be in proportion for other positions— $5/6$ ,  $4/6$ ,  $3/6$ , etc., of the full correction.

If corrections are made in this way, it is necessary to mark the position of each range-taker with a letter or number, and to ensure that each result handed in is marked to show the range-taker's position on the line.

#### Annual test practice

12. Practice annual tests should be performed, as often as convenient, before the actual test is carried out. One set of known ranges for the test is sufficient for any number of practices. The ranges must be accurate, however, and the tests should be conducted exactly as laid down.

13. In order that the men may be tested by the instructor on one of these occasions, the test should be carried out at least once either:—

- i. With ranges which are not known to the men.
- ii. With falsified ranges.
- iii. With a "reader" lying down in front of each man to ensure that the working head is turned off for each coincidence, and the range scale window is kept closed. The range-taker will call out each range as he reads it, and both he and the reader will write it down. The reader will also check each reading through the front range scale window.

## APPENDIX I

## SYLLABUS OF TRAINING

## General note.

The last half hour of each day's work should be devoted to (a) working out the day's results, (b) revision of all previous work and (c) short talks on such subjects as the importance of making coincidence from alternate sides, or the effect of bad halving, etc.

## 1st Stage, about three days.

Hours

Introductory lecture	...	...	...	...	1
General description—Packing and unpacking (Lesson 1)	...	...	...	...	2
Care and cleaning (Lesson 2)	...	...	...	...	2
Setting up instrument and focusing (Lesson 3)	...	...	...	...	1
Setting coincidence adjusting scale (Lesson 6)	...	...	...	...	$\frac{1}{2}$
Making coincidence (Lesson 4)	...	...	...	...	2
Halving adjustment (Lesson 5)	...	...	...	...	1
Taking ranges	...	...	...	...	7

## 2nd Stage, about six days.

Adjustment according to day's results (Lesson 7)	...	...	...	...	1
Making range cards (Lesson 11)	...	...	...	...	6
Taking ranges in rain and shimmer (Lesson 13)	...	...	...	...	1
Taking ranges	...	...	...	...	22

## 3rd Stage, about three days.

Coincidence on difficult objects (Lesson 12)	...	...	...	...	1
Making range cards (Lesson 11)	...	...	...	...	6
Calculation of consistency (Lesson 10)	...	...	...	...	2
Taking ranges	...	...	...	...	6

## 4th Stage, about six days.

Coincidence adjustment—Known range (Lesson 7)	...	...	...	...	1
Coincidence adjustment—Infinity (Lesson 8)	...	...	...	...	1
Practising adjustment of unknown instruments (Lesson 7)	...	...	...	...	4
Annual test practice (Sec. 14 and Appendix VI)	...	...	...	...	6
Practise adjustment on known ranges (Lesson 7)	...	...	...	...	2
Practise adjustment on moon and star (Lesson 8)	...	...	...	...	2
Practise adjustment on lath (Lesson 9)	...	...	...	...	4
Astigmatizer test (Appendix II)	...	...	...	...	1
Test of lath (Appendix II)	...	...	...	...	1
Taking ranges	...	...	...	...	8

## 5th Stage, about six days.

Hours

Use of cover and positions (Lesson 15)	...	...	...	...	2
Taking ranges to moving objects (Lesson 14)	...	...	...	...	3
Field duties (Lesson 16)	...	...	...	...	10
Taking ranges	...	...	...	...	15
T.O.E.T. (during hours of taking ranges in this period) (Sec. 14).	...	...	...	...	

## APPENDIX II

### INSTRUMENT TESTS

1. The two tests given below provide a means of testing the astigmatizers and lath in the field, and a range-taker must never adjust his instrument on a star or on the lath unless he knows that his instrument will pass the appropriate test.

These two tests are supplementary to the annual test of instruments given in the Handbook of the Range-Finder, Infantry, No. 12, 1933. The annual test requires the use of known ranges which will not be available in the field, yet the astigmatizers and lath must be tested.

#### i. The test of the astigmatizers.

Choose an object on which good coincidence can be made with or without the astigmatizers in use.

Take a series of 20 readings, in pairs, alternately with and without the astigmatizers.

The mean of the ten readings with the astigmatizers should not differ from the mean of the ten readings without them by more than  $8r^2$ .

#### ii. The test for difference in length between the adjusting lath and the base of the range-finder.

Adjust the instrument on a natural infinity (moon by day). Set up the lath at about 200 yards from the range-finder, great care being taken that it is parallel to the base of the instrument.

Take a series of ten readings on the lath. The accuracy figure should be less than  $10r^2$  (one division).

2. As in the adjusting of his instrument, the range-taker should work out the consistency of the series taken, to ensure that the results are reliable.

## APPENDIX III

### DETERMINATION OF KNOWN RANGES

1. Known ranges are necessary for the training of range-takers, and it must be ensured that they are known with sufficient accuracy.

No known range should be used in training or in tests unless there is a record of how it was obtained, and of the maximum error. The maximum error must be:—

- i. For adjusting the instrument—less than  $r^2$ .
- ii. For testing the man—less than  $2r^2$ .

During the first stages of training, ranges may be used which are not so accurately known, but the maximum error must always be small compared with the error which the man may make.

2. In general, the determination of ranges should be entrusted to a surveyor, or an officer who has some knowledge of the errors which he may expect to make. Some idea of the methods of calculating these errors is given below.

When found, all ranges should be recorded in a book, showing the method by which they were obtained and the maximum error. The two ends of the range should be adequately described and, if necessary, should be marked on the ground in some permanent way.

3. **Measurement by survey.**—This is the most satisfactory method, where military survey personnel are available. The accuracy required should be specified before the survey, and the accuracy obtained must be given by the surveying officer.

4. **Calculation from trigonometrical co-ordinates.**—A list of trig. points and their co-ordinates may be obtained from command headquarters. The distance between any two of these points may be found by calculation, as follows: Subtract the east co-ordinates and subtract the north co-ordinates. The two figures obtained are, in metres, the lengths of two sides of a right-angled triangle; the third side is the range required, and this can be calculated and converted to yards. The maximum error in the trig. points will be less than one foot.

A range found in this way may be altered by means of the steel tape and range-finder methods described below.

5. **Measurement with steel tape over flat ground.**—This method is not accurate over long distances without the use of special instruments, but it can be used for the measurement of distances up to 250 yards in increasing or decreasing

a surveyed range. The maximum error may be taken as the sum of the maximum errors of the survey and of the measurement by tape. The error in using a steel tape is not likely to exceed 1 per cent.

*Example.*

Surveyed range of 2000 yards. Maximum error stated by surveyor to be (say) ... 3 yards.  
 200 yards measured away from base.  
 Maximum error of measurement ... 2 yards.  
 Maximum error of new range of 2200 yards is therefore 3 plus 2 yards = 5 yards.  
 As 5 yards is  $1r^2$  of 2200 yards, the new range is known to within  $r^2$ .

**6. Measurement with the range-finder.**—The maximum error of a trained range-taker in good conditions on a good object immediately after adjusting his instrument is  $8r^2$ . This is not sufficiently accurate for practising other men, but greater accuracy may be obtained by the following methods.

When using methods i. and ii., to ensure that there is no unusual error, it is advisable for two trained range-takers to take the ranges, and for them to check the adjustment of their instruments again afterwards.

i. A surveyed range may be increased or decreased by a distance of more than 250 yards in the same way as with a steel tape (*see* para. 5, above). In calculating the maximum error of the new range, the error of the range-finder on the distance is taken to be  $8r^2$ .

ii. If a fairly long range is taken in sections, it will be found that greater accuracy is obtained. For instance:—

Error in taking a range of 2000 yards ( $8r^2$  of 2000), 32 yards; but error in taking half the range ( $8r^2$  of 1000), 8 yards.

So, if the two halves were taken and added together, the error will be only 16 yards, instead of 32 yards.

The more sections taken the more accurate will be the range. If a range is taken in four approximately equal sections, the accuracy will be within  $2r^2$ , and, if in eight sections, within  $r^2$ .

This method will only be possible on flat ground.

iii. If a range is taken several times on different occasions, or by different range-takers, the mean of all the series will be more accurate than if only one series were taken. The accuracy increases as the square root of the number of series, so to obtain an accuracy of  $2r^2$

the mean of 16 series must be taken, and to obtain an accuracy of  $r^2$  the mean of 64 series is required.

This method of finding known ranges will be found very useful, because it is only necessary to collect the results of trained range-takers in their normal practice over a sufficiently long period, and a great number of ranges will be obtained. It must be ensured that every series used is by a trained man, on a good object, and immediately after adjusting his instrument.

**7. Measurement from a map.**—Maps do not give ranges with great accuracy. When used, they must be clean and unfolded, and points must be accurately located. The chief error is likely to be the distortion of the map, and this must always be allowed for by one of the methods described below.

i. On a gridded map, read the co-ordinates of the two ends of the range required as accurately as possible, and then calculate the range in the manner described in para. 4, above. This method automatically allows for most of the distortion of the map.

ii. Make several measurements with a ruler measuring in one-fiftieth inch, or graduated in yards and feet, and find the mean of all the measurements taken. Distortion must then be allowed for, and this will normally be different in different directions of the map. If two trig. points can be selected in approximately the same direction as the range measured, the distance between these should be measured on the map, and the true distance calculated as described in para. 4, above. The difference between the calculated and measured distances will show the error of the map in that direction, and the measured range can be altered in the same proportion.

When the range has been taken from a map by either of these methods, the error can be taken to be 0.04 inch. On a 6 inches to the mile map this represents 11.7 yards, and on a 25 inches to the mile map it represents 2.8 yards. Thus on the 6-inch map only ranges of over 3400 yards can be found to within  $r^2$ , and ranges over 2400 yards to within  $2r^2$ . The 25-inch map gives the same accuracy at about half these ranges.

There are certain aids to measurement, such as a travelling microscope, which will increase the accuracy obtained, and these should be used whenever possible.

## APPENDIX IV

VALUES OF  $r^2$ 

1. All errors in range-taking are given in terms of  $r^2$ , which is the square of the range in thousands of yards. The following example shows the method of calculation.

Range, 1700 yards.  $r^2$  is  $1.7 \times 1.7$ . 2.9 yards,

Error, 20 yards, which is  $\frac{20}{2.9} r^2$ , or  $7r^2$ ,

where the error given may be either a mean deviation (accuracy) or a mean residual (consistency).

For convenience in working out accuracy and consistency figures in training, a table of "values of  $r^2$ " is given in this appendix, and a calculator is issued for the use of instructors.

2. Instructions for using table of values of  $r^2$ .—

The range is given on the left of the table, the accuracy figure (A.F.) or consistency figure (C.F.) along the top, and the number of yards in the body of the table.

*Example.*

i. Required— $14r^2$  at 1450 yards.

at 1450 yards  $10r^2$  is 21 yards.

$4r^2$  is 8 yards.

so  $14r^2$  is 29 yards.

ii. Required—the A.F. or C.F. for 99 yards at 2750 yards.

At 2750 yards 76 yards is  $10r^2$

remainder 23 yards is  $3r^2$

so 99 yards is  $13r^2$

## 3. Use of range-taking calculator.—

Set the " $r^2$ " arrow on the foot of the slide against the range. Then the A.F. or C.F. at the top of the slide will be opposite the number of yards on the upper scale of the rule.

*Example.*

Range 2120 yards (set arrow as near as possible).

$6r^2$  (6 on the slide) is 27 yards (on upper scale);

and 40 yards (on upper scale) is  $9r^2$  (9 on slide).

VALUES OF  $r^2$ 

Range	$r^2$								
	1	2	3	4	5	10	15	20	25
600	0	1	1	1	2	4	5	7	9
50	0	1	1	2	2	4	6	8	11
700	0	1	1	2	2	5	7	10	12
50	1	1	2	2	3	6	8	11	14
800	1	1	2	3	3	6	10	13	16
50	1	1	2	3	4	7	11	14	18
900	1	2	2	3	4	8	12	16	20
50	1	2	3	4	5	9	14	18	23
1000	1	2	3	4	5	10	15	20	25
50	1	2	3	4	6	11	17	22	28
1100	1	2	4	5	6	12	18	24	30
50	1	3	4	5	7	13	20	26	33
1200	1	3	4	6	7	14	22	29	36
50	2	3	5	6	8	16	23	31	39
1300	2	3	5	7	8	17	25	34	42
50	2	4	5	7	9	18	27	36	46
1400	2	4	6	8	10	20	29	39	49
50	2	4	6	8	11	21	32	42	53
1500	2	4	7	9	11	22	34	45	56
50	2	5	7	10	12	24	36	48	60
1600	3	5	8	10	13	26	38	51	64
50	3	5	8	11	14	27	41	54	68
1700	3	6	9	12	14	29	43	58	72
50	3	6	9	12	15	31	46	61	77
1800	3	6	9	13	16	32	49	65	81
50	3	7	10	14	17	34	51	68	86
1900	4	7	11	14	18	36	54	72	90
50	4	8	11	15	19	38	57	76	95
2000	4	8	12	16	20	40	60	80	100
50	4	8	13	17	21	42	63	84	105
2100	4	9	13	18	22	44	66	88	110
50	5	9	14	18	23	46	69	92	116
2200	5	10	15	19	24	48	73	97	121
50	5	10	15	20	25	51	76	101	127
2300	5	11	16	21	26	53	79	106	132
50	6	11	17	22	28	55	83	110	138
2400	6	12	17	23	29	58	86	115	144
50	6	12	18	24	30	60	90	120	150
2500	6	12	19	25	31	62	94	125	156
50	7	13	20	26	33	65	98	130	163
2600	7	14	20	27	34	68	101	135	169
50	7	14	21	28	3	70	105	140	176
2700	7	15	22	29	36	73	109	146	182
50	8	15	23	30	38	76	113	151	189
2800	8	16	24	31	39	78	118	157	196
50	8	16	24	32	41	81	122	162	203
2900	8	17	25	34	42	84	126	168	210
50	9	17	26	35	44	87	131	174	218
3000	9	18	27	36	45	90	135	180	225
50	9	19	28	37	47	93	140	186	233
3100	10	19	29	38	48	96	144	192	240
50	10	20	30	40	50	99	149	198	248
3200	10	20	31	41	51	102	154	205	256
50	11	21	32	42	53	106	158	211	264
3300	11	22	33	44	54	109	163	218	272
50	11	22	34	45	56	112	168	224	281
3400	12	23	35	46	58	116	173	231	289
50	12	24	36	48	60	119	179	238	298
3500	12	24	37	49	61	122	184	245	306

## APPENDIX V

## APPARATUS, TRAINING RANGE-TAKERS

1. This apparatus is designed to allow of the training of the range-taker indoors where outdoor facilities are not available.

The apparatus consists of an arrangement of lenses and mirrors which allows a range to be taken to any photograph, sketch or lantern slide, using an ordinary range-finder.

The apparatus is very inaccurate, because the fitting of the slide or picture to the holder and the type of slide or picture used not only cause a large variation in the general range to the picture but also in the range to different parts of the picture.

The apparatus has a pointer which may be set to "short" "medium" or "long" range, which can be set to give approximately the range which it is desired to record.

2. Training on the apparatus should follow as nearly as possible the sequence laid down for outdoor work.

3. In the first stages of training it will be sufficient to practise the range-taker in taking series without any testing, except that the instructor should sometimes check the readings of the range scale by looking through the left eyepiece.

4. Owing to the inaccuracy of the apparatus, a known range is not available, but the adjustment of the range-finder can be practised in the following way :—

- i. The range-taker takes a series of readings.
- ii. The instructor gives a *true range*, which is about  $6r^2$  to  $15r^2$  from the *mean observed range*.
- iii. The range-taker works out his accuracy figure, moves the coincidence adjusting head accordingly, and takes another series. The mean observed range should now be within  $5r^2$  of the supposed true range.

*Notes.*—The range pointer on the apparatus must not be moved, and the slide or picture should not be touched, between these two series.

Coincidence must be made throughout not only on the same object but on the same part of the object.

The adjustment found by this means will have no relation to the adjustment required to take ranges out of doors.

5. When it is necessary to adjust the apparatus, this will be done by an armourer, assisted by a trained range-taker. Complete instructions for adjustment are contained in the pamphlet issued with each apparatus.

## APPENDIX VI

## ANNUAL TEST

1. Immediately before the test, each man will be given unlimited time to adjust his instrument on a known range of between 2000 and 3000 yards. The range to this object, which should have a well-defined straight edge, must be known to  $r^2$

## 2. Object.

- i. The object is to test the man's ability to produce without delay reliable ranges on two natural objects which represent the position of own troops and enemy; the objects to be indicated verbally.

- ii. *Procedure.*—Two directors are laid on objects representing :—

*Enemy.*—Range between 1500 and 2000 yards.

*Own troops.*—Range between 1000 and 1500 yards.

There must be at least 200 yards between the two objects.

The objects must be approximately in the same line.

The men to be tested will set up their instruments on the testing site and stand up behind their instruments.

- iii. *The test.*—The officer conducting the test will indicate the two objects verbally to the men undergoing the test. Before doing so he will warn them that the indication will not be repeated and that any man who fails to recognize either or both objects from his indication may do so by means of the directors, no extra time being allowed.

At the end of the indication the men will lie down behind their instruments and take the ranges without further orders.

Time limit (timed from the end of the indications) :

6 minutes.

On completion of the test each range-taker will hand to the conducting officer the range to "Enemy" and "Own troops" filled in on a prepared slip.

### 3. Marking and classification.

Each of the two ranges will be awarded points as follows:—

10 <i>points.</i>	5 <i>points.</i>	<i>Minus 5 points.</i>
within $20r^2$	within $25r^2$	more than $35r^2$

Range-takers will be classified as under:—

Qualified—over 12 points.



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